Welcome to the *Climate-Safe Infrastructure* Webinar Series

Supporting AB2800 and the Work of California's Climate-Safe Infrastructure Working Group

February 22, 2018 | 12-1pm

CALIFORNIA natural resources AGENCY

Hosts

Juliette Finzi Hart | USGS

Co-Facilitator of CSIWG’s work

Email: jfinzihart@usgs.gov

Susi Moser | Susanne Moser Research & Consulting

Co-Facilitator of CSIWG’s work

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AB 2800 (Quirk): Purpose

Examine how to integrate scientific data concerning projected climate change impacts into state infrastructure engineering, including oversight, investment, design, and construction.

AB 2800 (Quirk):
Scope of Assessment and Recommendations

The working group shall consider and investigate, at a minimum, the following issues:

(1) **informational and institutional barriers** to integrating climate change into infrastructure design.

(2) **critical information needs** of engineers.

(3) **selection of appropriate engineering designs** for different climate scenarios.

The *Climate-Safe Infrastructure* Webinar Series

Purpose

- Hear from others elsewhere with relevant experience and expertise.
- Hear from CSIWG members.
- Educate and engage with interested stakeholders on climate change and infrastructure issues.

Sample of Webinar Topics

- What climate science can offer
- Various sectoral perspectives
- Processes of changing engineering standards and guidelines
- Holistic infrastructure planning and management
- Financing climate-safe infrastructure
- And others…

A Couple of Housekeeping Items

- Please type your questions for presenters into the chat box
- We will try to answer as many as possible after the presentations
- Answers to remaining questions will be posted on the website

Today's Webinar:

Forward-Looking Climate Science for Use in Infrastructure Engineering: Possibilities and Limits

Dan Cayan, Ph.D. | Researcher | Climate-Safe Infrastructure Working Group Member

Scripps Institution of Oceanography

Patrick Barnard, Ph.D. | Research Geologist USGS Pacific Coastal & Marine Science Center

Nicolas Luco, Ph.D. | Research Structural Engineer | USGS Geologic Hazards Team

Morgan Page, Ph.D. | Geophysicist

USGS Earthquake Science Center

Climate Model Projections for Decision Making in California

AB2800 Webinar 22 Feb 2018

Dan Cayan, David Pierce, Julie Kalansky

Scripps Institution of Oceanography

University of California San Diego

Guidance from Juliette and Susi

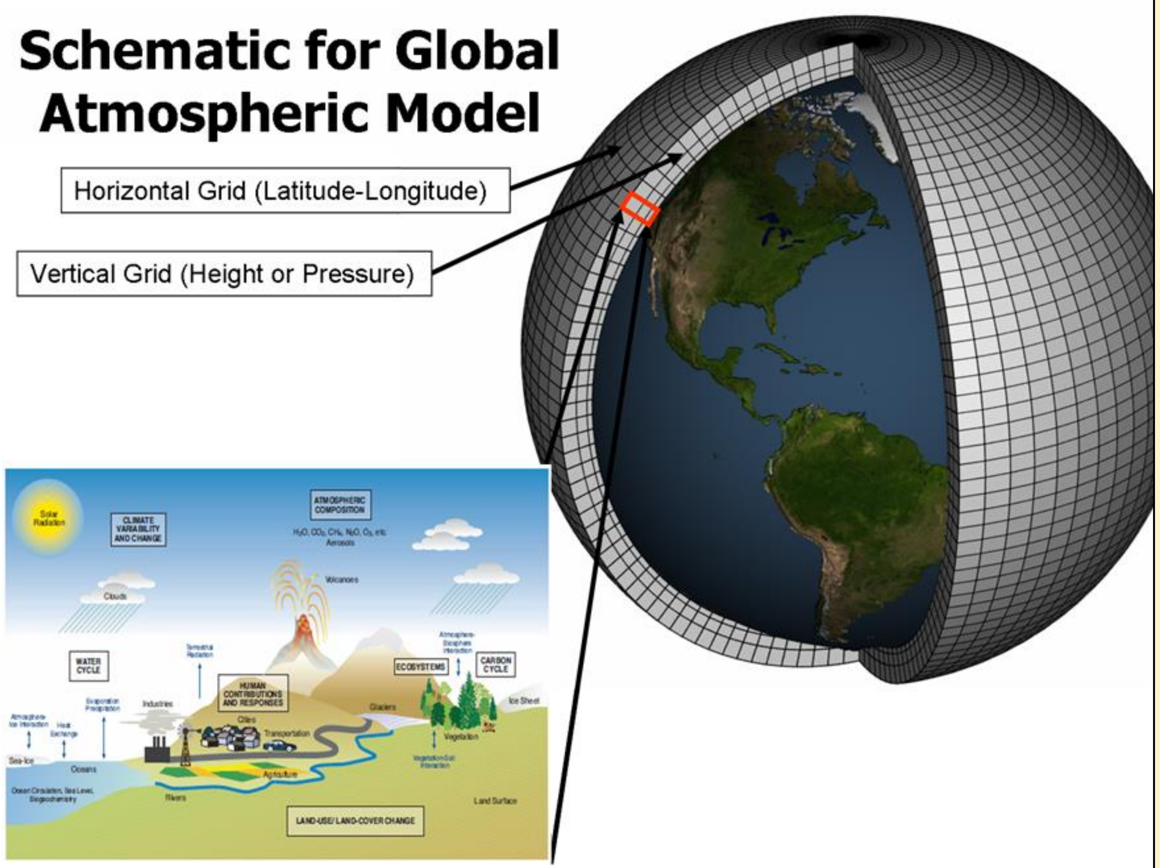
From what we've been hearing in the WG meetings and the literature we've read so far… the two main obstacles to incorporating forward-looking climate science by engineers into design and standards seem to be 1) inadequate understanding of how GCMs are developed (e.g., the science embedded therein and how models are validatied/groundtruthed) and 2) what options we have in areas where there remains (for the foreseeable future) large ranges of uncertainty. We're giving you a longer time for your presentation since we have the most requests for what we'd like you to cover, which include:

What types of information go into GCMs … of these, what types of information are we most confident in, which ones the least? As part of this, we would be interested in hearing about how validation usually happens (i.e. do most modelers do some sort of hindcast to make sure the models match historic projections… then they push forward? do they ground truth their models? what about judging "skill" - how is that done? what do we know about which models are better than others?) [we just learned about some Australian approach to weighing models by skill; maybe you can speak to the value of such approaches]

Then you could discuss what's currently available in California … (we heard in the meeting the need for information on intensity and duration of rain fall and run-off; more SLR info (!!!!) so you should definitely address those)

Then spend some time discussing the trends that we expect to see and perhaps the growing variability around the extremes …of the extremes - which ones do we understand the most; which the least. Where do you expect significant progress in the next 3-5 years? What do you expect to remain extremely uncertainty?

Finally - if time permits - you could discuss what information we could turn to for either information that hasn't yet been modeled and/or has huge uncertainty…. perhaps discussing spatial analogs (e.g. if we're expecting less night time cooling… we could look at how places in the middle east address this impact on their energy infrastructure) or historical analogs or very big historical extremes.



Global Climate Models

Continued development, more processes

Skillfully simulate Earth’s surface temperature;
- historical decade-scale temperature well replicated
- demonstrate that GHG’s have driven warming in recent decades

Uncertainties
- model approximations
- drivers of climate change (e.g. GHGs, aerosols)
- natural variation

More Certain Future outcomes:
- warming earths’ surface
- overall speed up of hydrological cycle, atmospheric humidity
- sea level rise
- loss of snow pack
- increase in some forms of extremes (e.g. drought, heavy precip)

Less Certain Future outcomes
- changes in overall precipitation
- changes in storminess
- changes in wind patterns

GCM Evaluation
global metrics

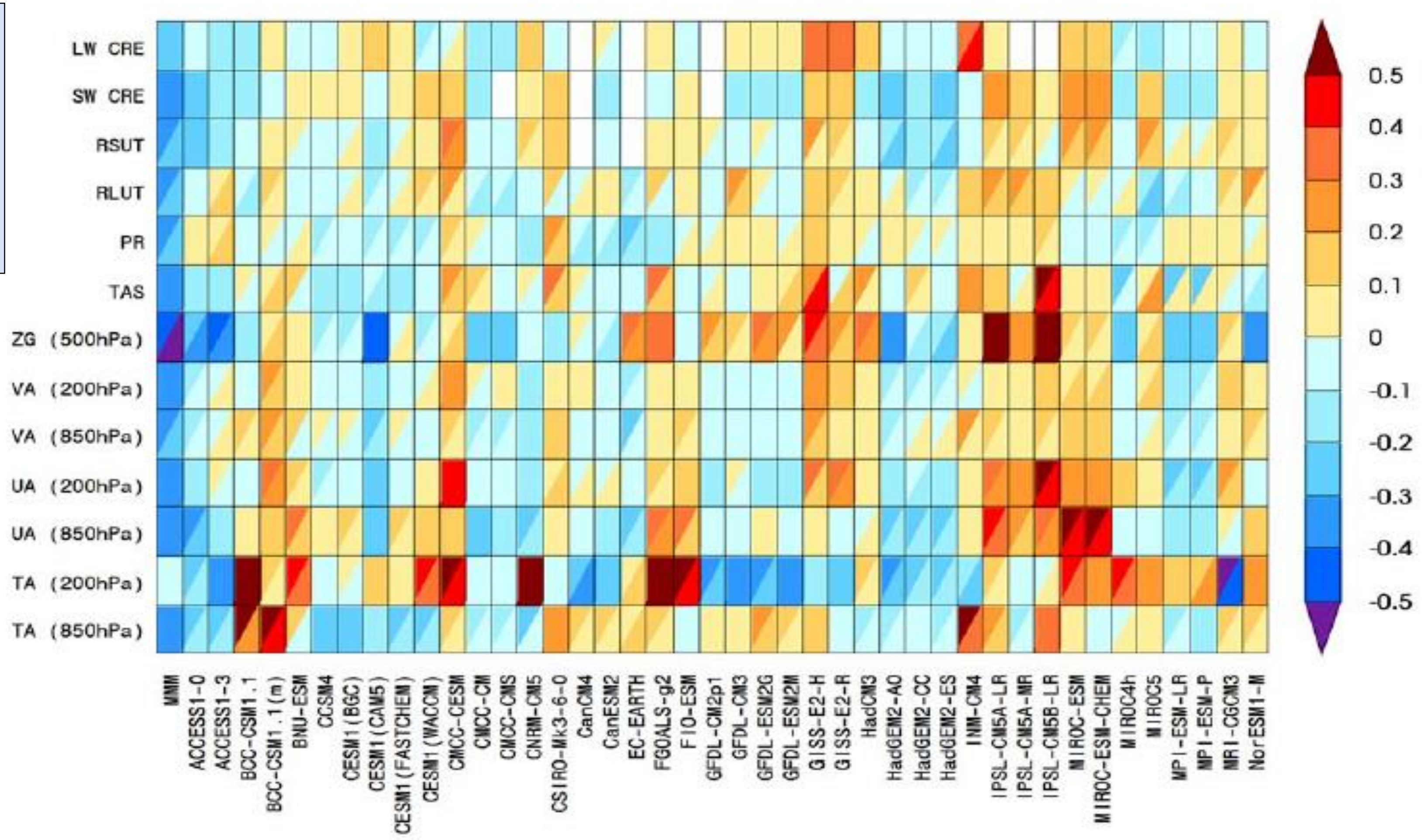


Figure 9.7: Relative error measures of CMIP5 model performance, based on the global seasonal-cycle climatology (1980–2005) computed from the historical experiments. Rows and columns represent individual variables and models, respectively. The error measure is a space–time root-mean-square error (RMSE), which, treating each variable separately, is portrayed as a relative error by normalizing the result by the median error of all model results (P. Gleckler, Taylor, & Doutriaux, 2008). For example, a value of 0.20 indicates that a model's RMSE is 20% larger than the median CMIP5 error for that variable, whereas a value of –0.20 means the error is 20% smaller than the median error. No color (white) indicates that model results are currently unavailable. A diagonal split of a grid square shows the relative error with respect to both the default reference data set (upper left triangle) and the alternate (lower right triangle). The relative errors are calculated independently for the default and alternate data sets. All reference data used in the diagram are summarized in Table 9.3.

Peter Gleckler: from IPCC AR5 Working Group I, draft, not for distribution

Identifying GCMs for California Water Managers

- For many purposes, an ensemble of global models is required
- Using all 40+ available Global Climate Models (GCMs) isn't practical
- Remove (cull) GCMls that don't adequately represent historical conditions i

40+ GCMs

Global Climatology Assessment

Gleckler et al IPCC 5th Assessment Report evaluated modeled historical

- Radiation
- Temperature
- Pressure, wind

~20 GCMs

Regional Assessment

Rupp, Mote et al Southwestern U.S.

- Temperature & Precipitation
- Pressure patterns, El Niño structure

~15 GCMs

CA/NV Extremes Assessment

Cayan et al CNAP, SW CSC Group

- Dry and Wet Precipitation extremes
- Heat waves and cold snaps
- El Niño spatial & temporal patterns

~12 GCMs

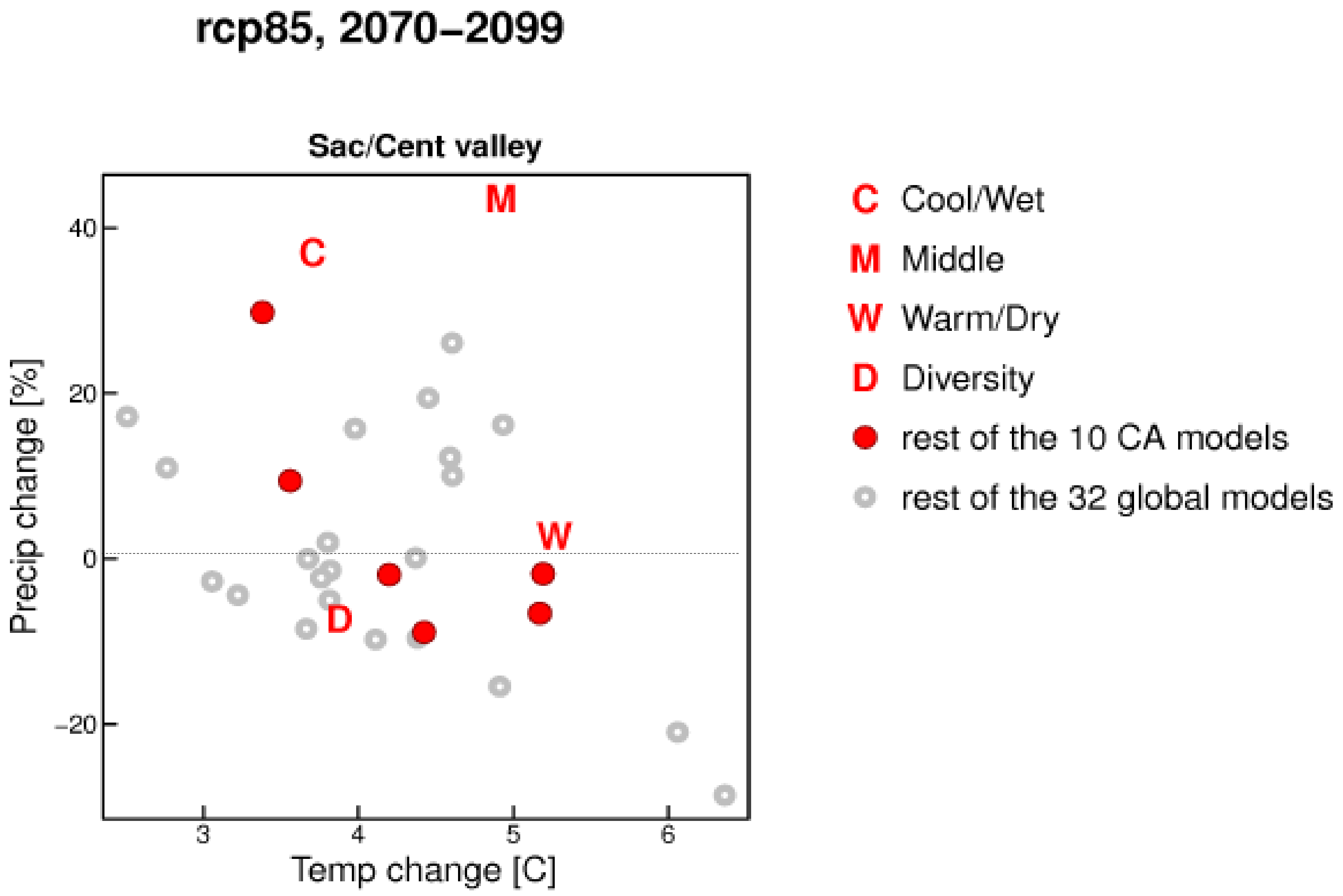
A subset of GCMs for

California Water Resources Assessment

Numbers of GCMs to be retained after Global, Regional Mean and Regional Extremes Assessments are a preliminary estimate

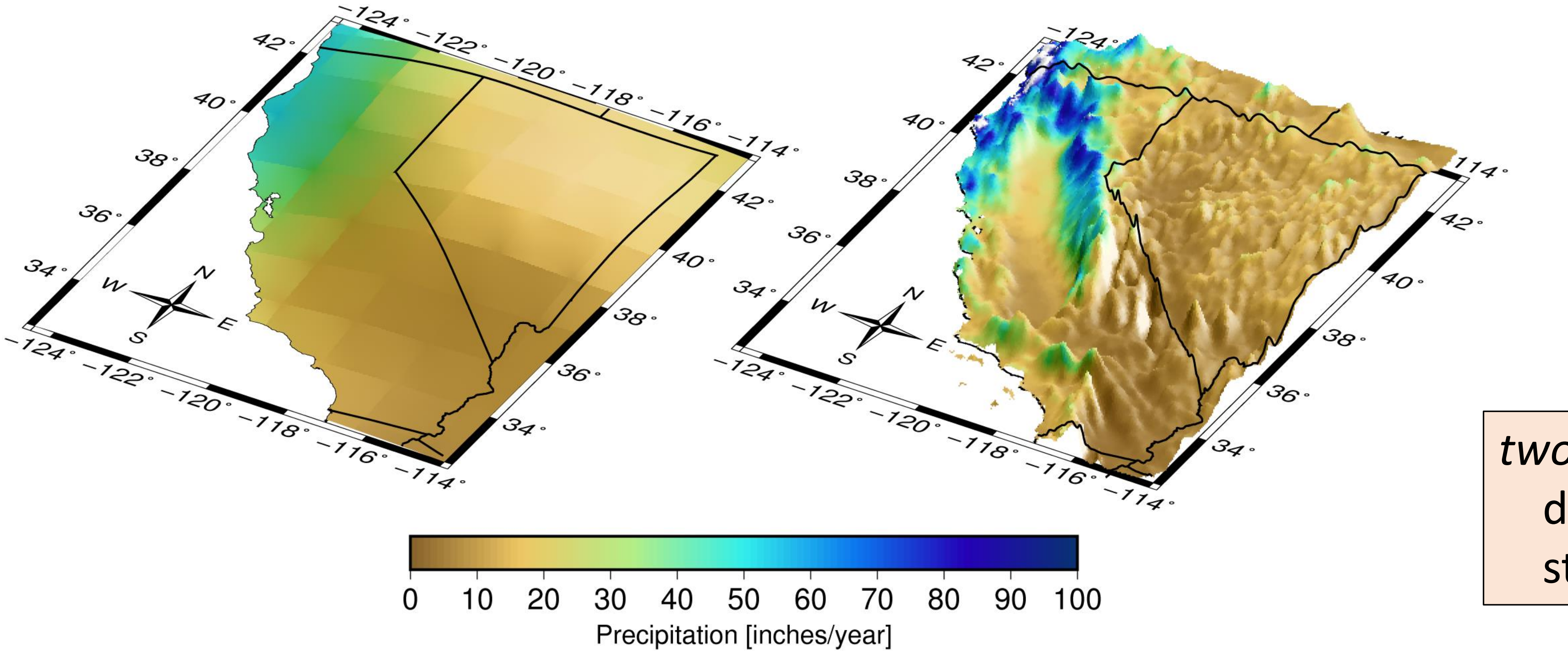
Temperature Change and Precipitation Change near Sacramento

RCP8.5, 2070-2099 vs. 1950-2005 all 32 GCMs, and selected 10 GCMs, 4 GCMs



Downscaling

from global climate model output to regional climate simulations



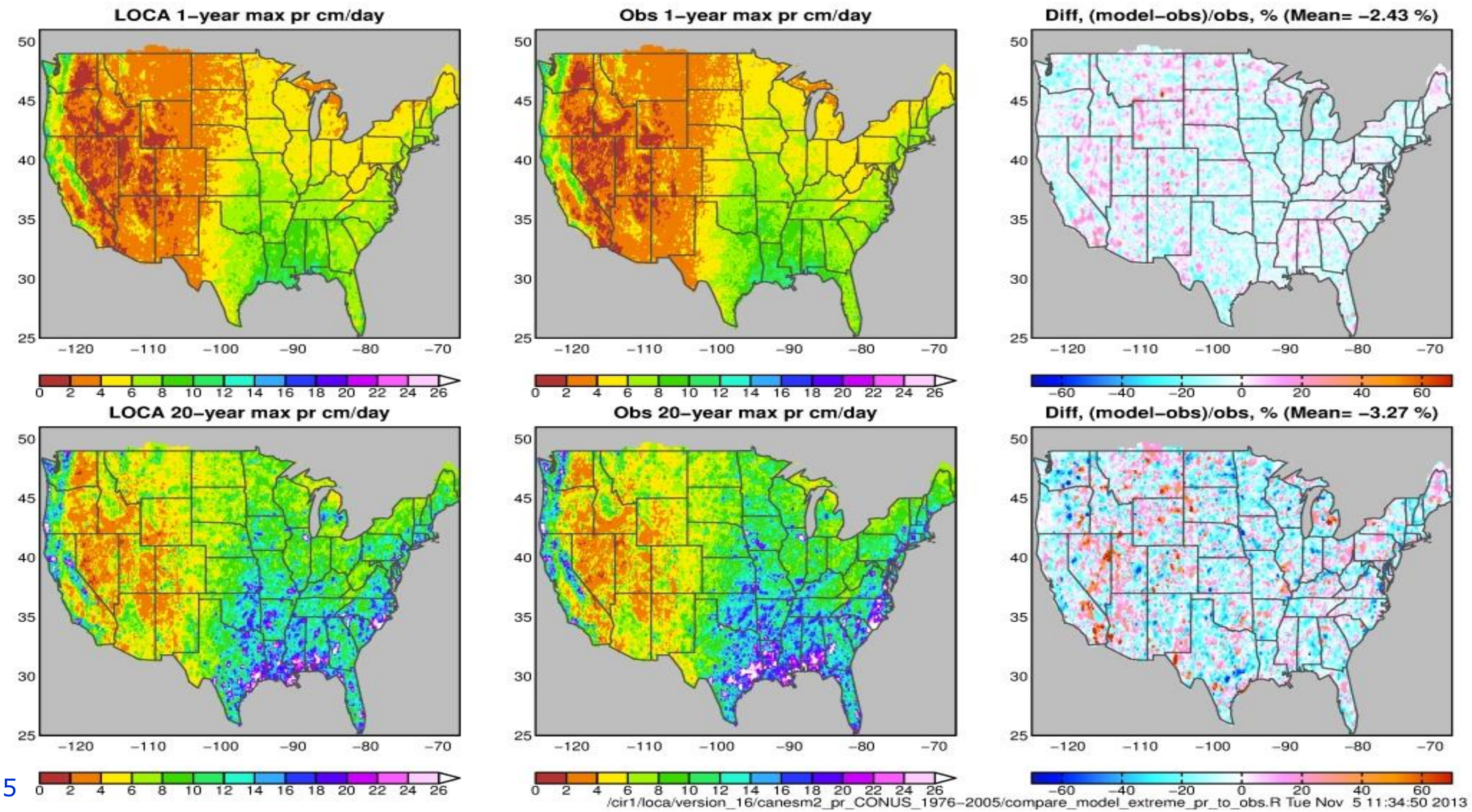
two techniques
dynamical
statistical

Figure 1 Annual precipitation in California and Nevada (inches) in a global climate model with a resolution of 100 miles (left), and after using a statistical model to account for the effects of topography at a 3.6 mile resolution (right). The global model only has a few grid cells over the entire state of California, so does not resolve the coastal mountain ranges, interior valley, or Sierra Nevada Mountains on the border with Nevada. The precipitation field in the right panel, by contrast, captures the wet conditions on the west slopes of the mountains, and the dry, rain shadow region to the east of the mountains. The vertical scale has been exaggerated for clarity, and by the same amount in both panels.

LOCA statistical downscaling designed to simulate extremes:

extreme precipitation LOCA vs Observed

historical CanESM2 1yr and 20 yr maximum precipitation

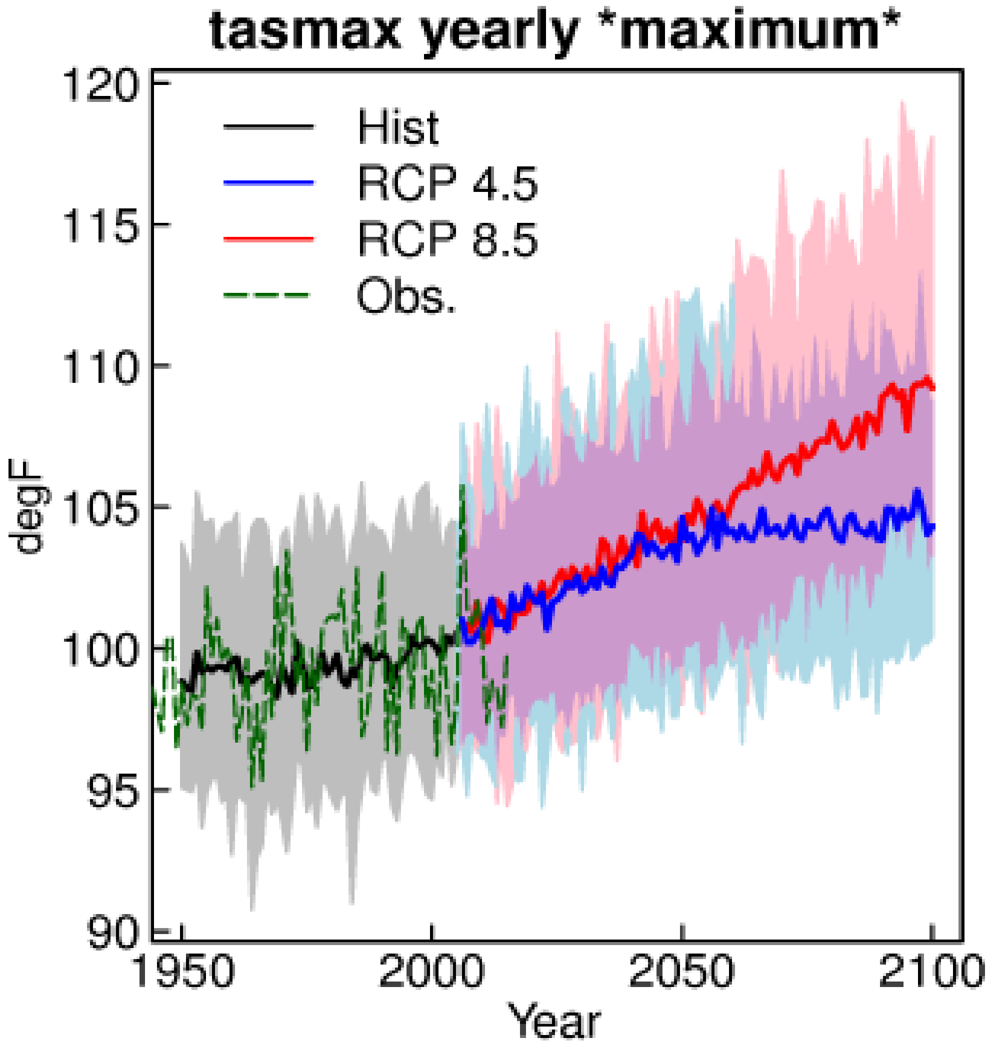


Hottest Day of the Year will likely get hotter!

from 32 downscaled CMIP5 GCMs averaged over San Diego County
moderate (RCP 4.5) and high (RCP 8.5) greenhouse gas emissions scenarios

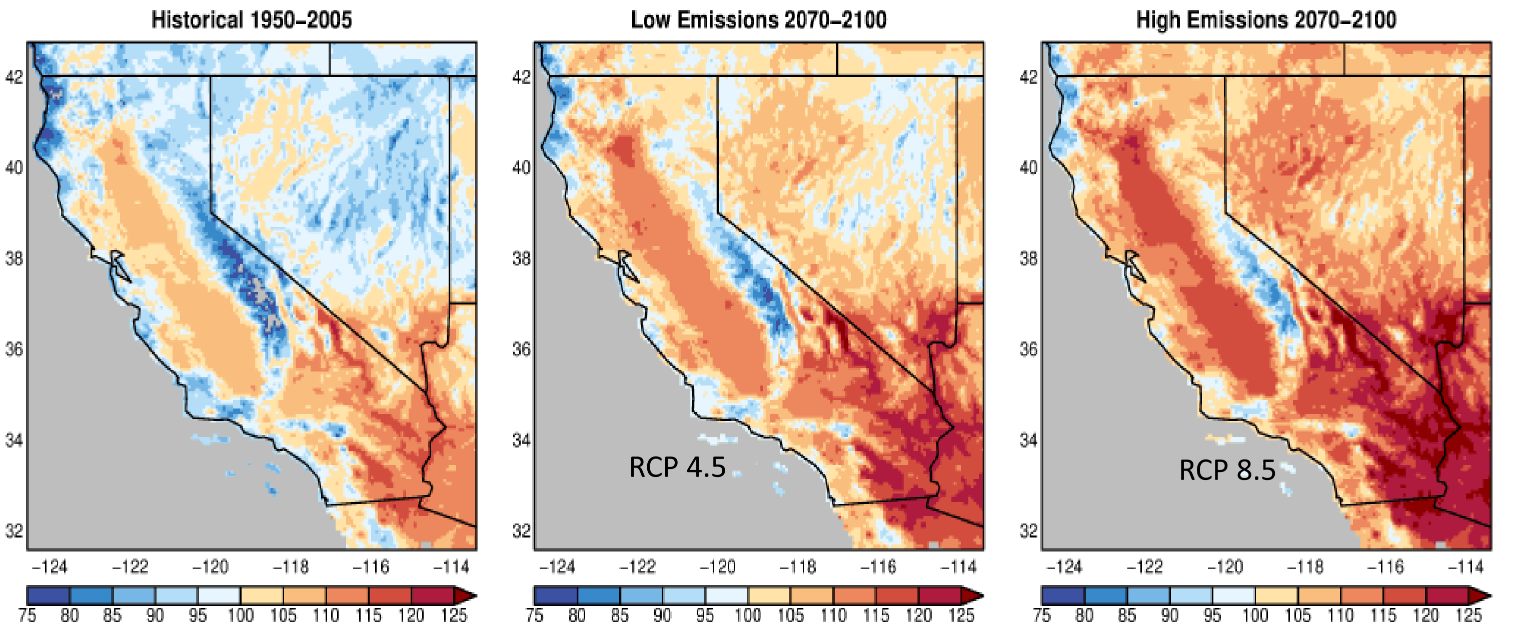
RCP 8.5 greenhouse loading excesses over RCP 4.5 become increasingly large, especially after 2050.

Dark lines are averages over 32 models,
Clouds show range of model results for each year



David Pierce, SIO

Hottest day of the year, historical vs. end of century (deg F)



Change in hottest day of the year (deg F):

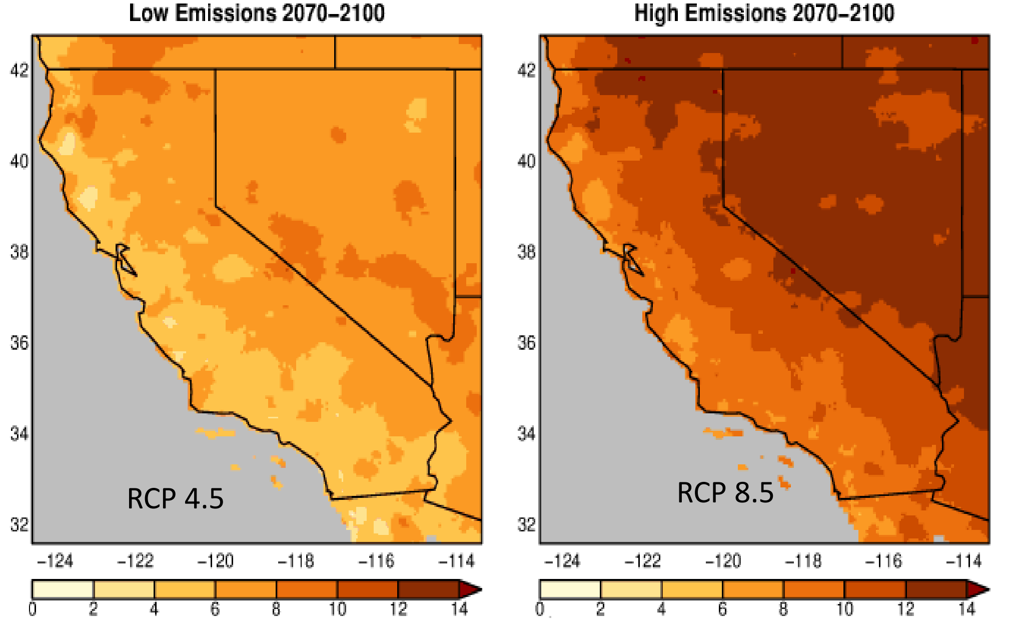


Figure 5

David W. Pierce, Scripps Institution of Oceanography

Range of Number of Days/year >= threshold (deg F): RCP 8.5

(range encompasses 2/3rds of years)

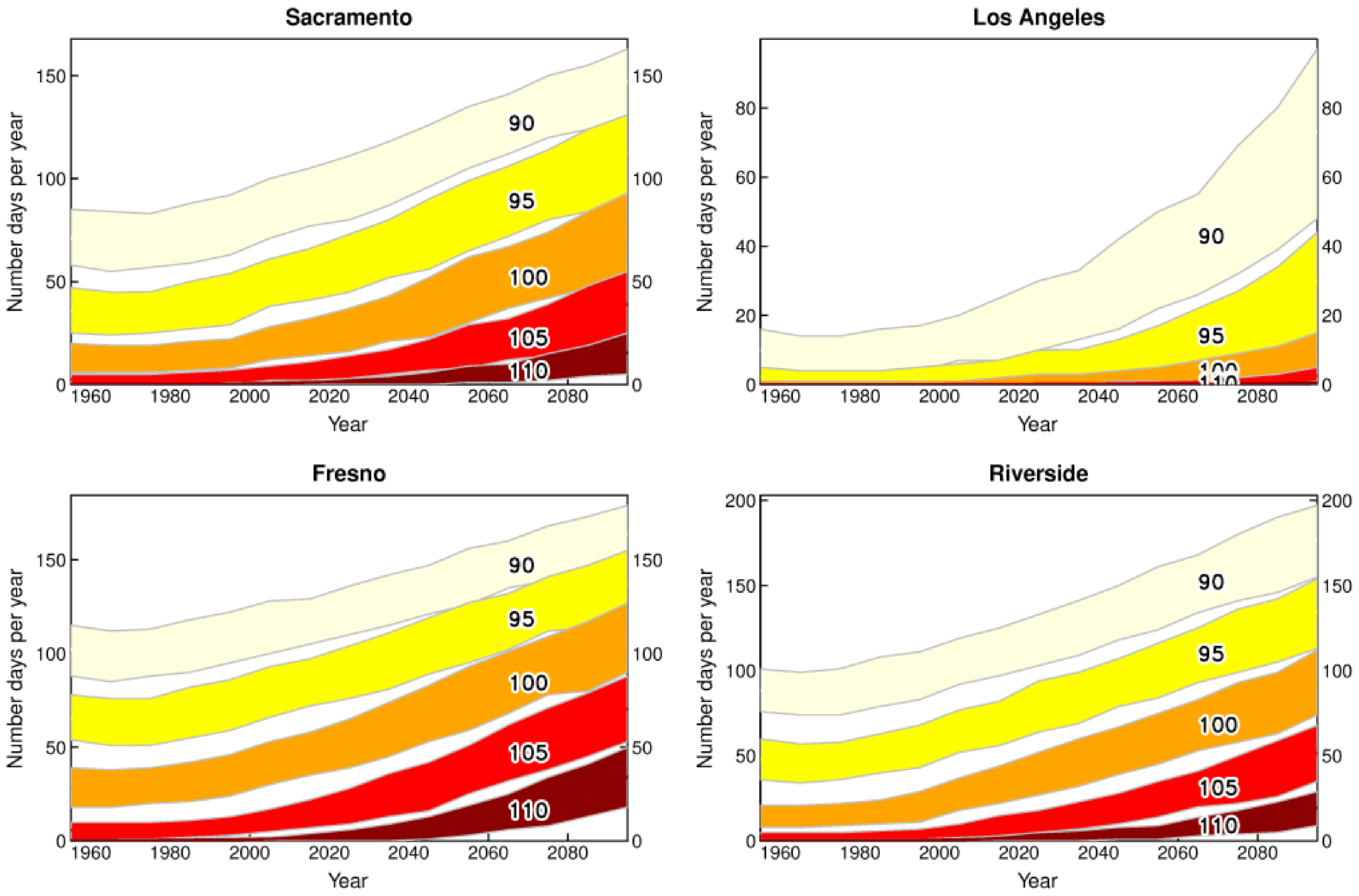


Figure 6

David W. Pierce, Scripps Institution of Oceanography

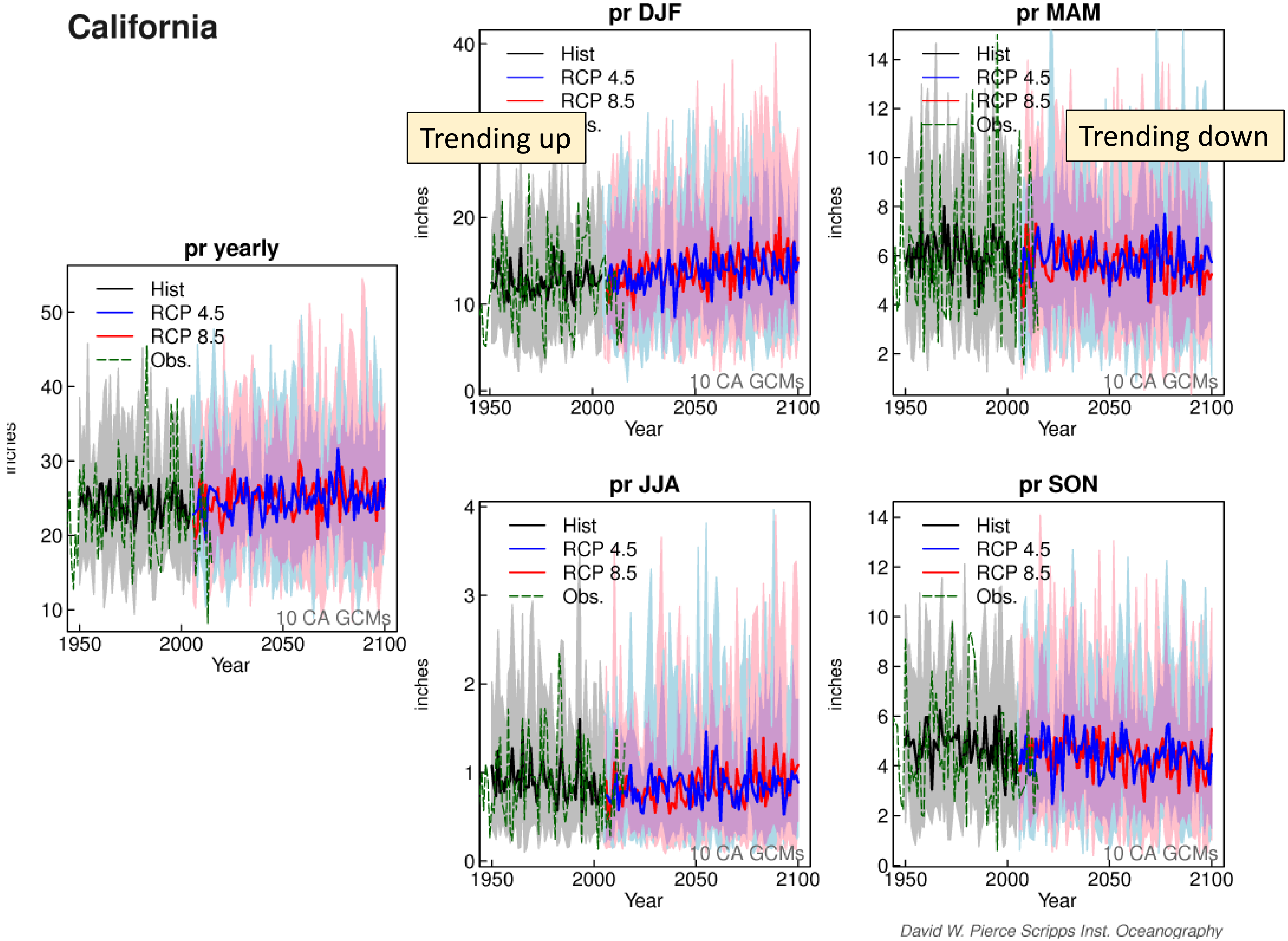

California
pr yearly
pr DJF
pr MAM
pr JJA
pr SON
Hist
RCP 4.5
RCP 8.5
Obs.
inches
Year
10 CA GCMs
Trending up
Trending down
David W. Pierce Scripps Inst. Oceanography

Figure 7

Frequency of Dry Years, California

32 GCMs

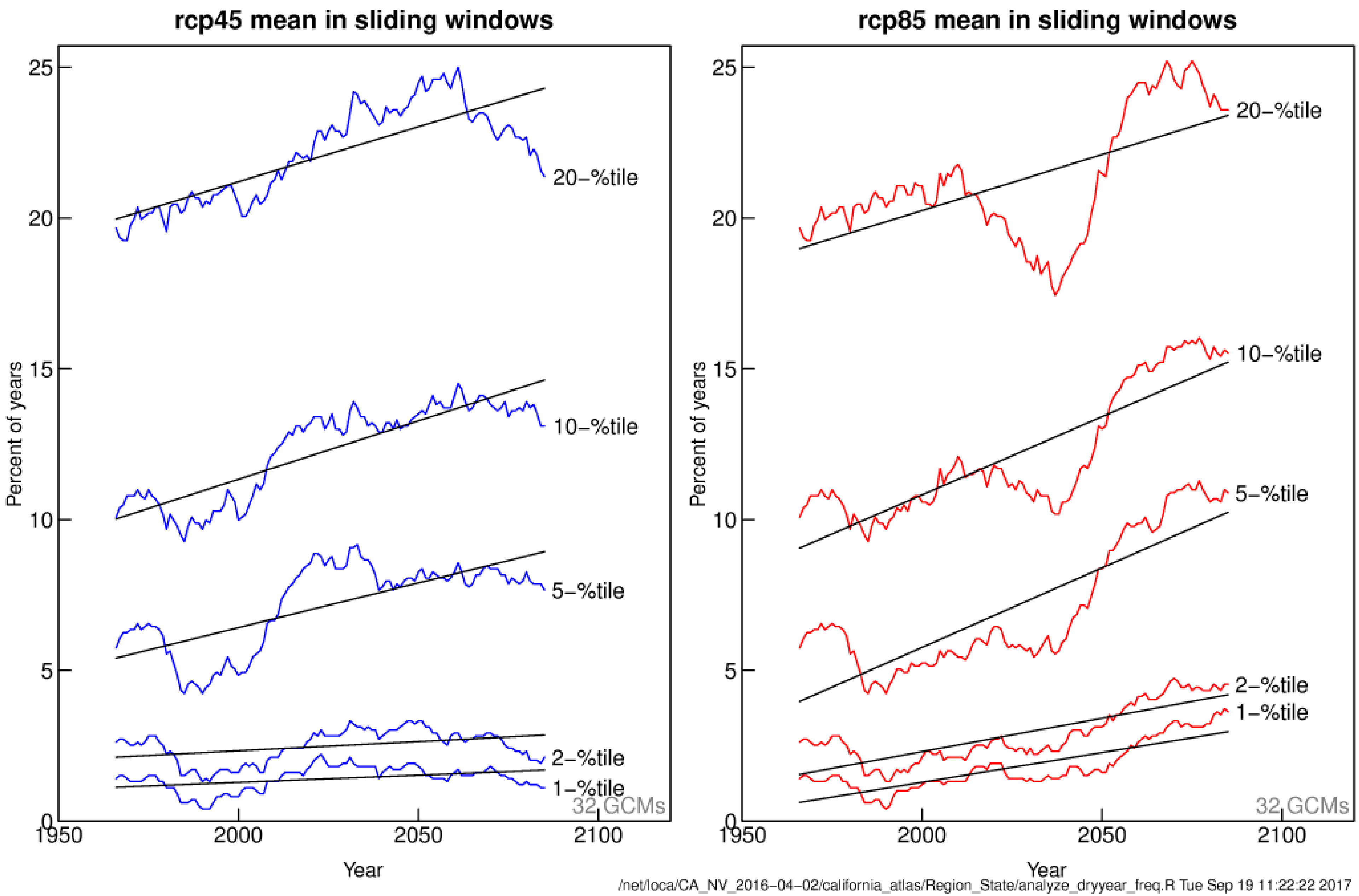


Figure 12a

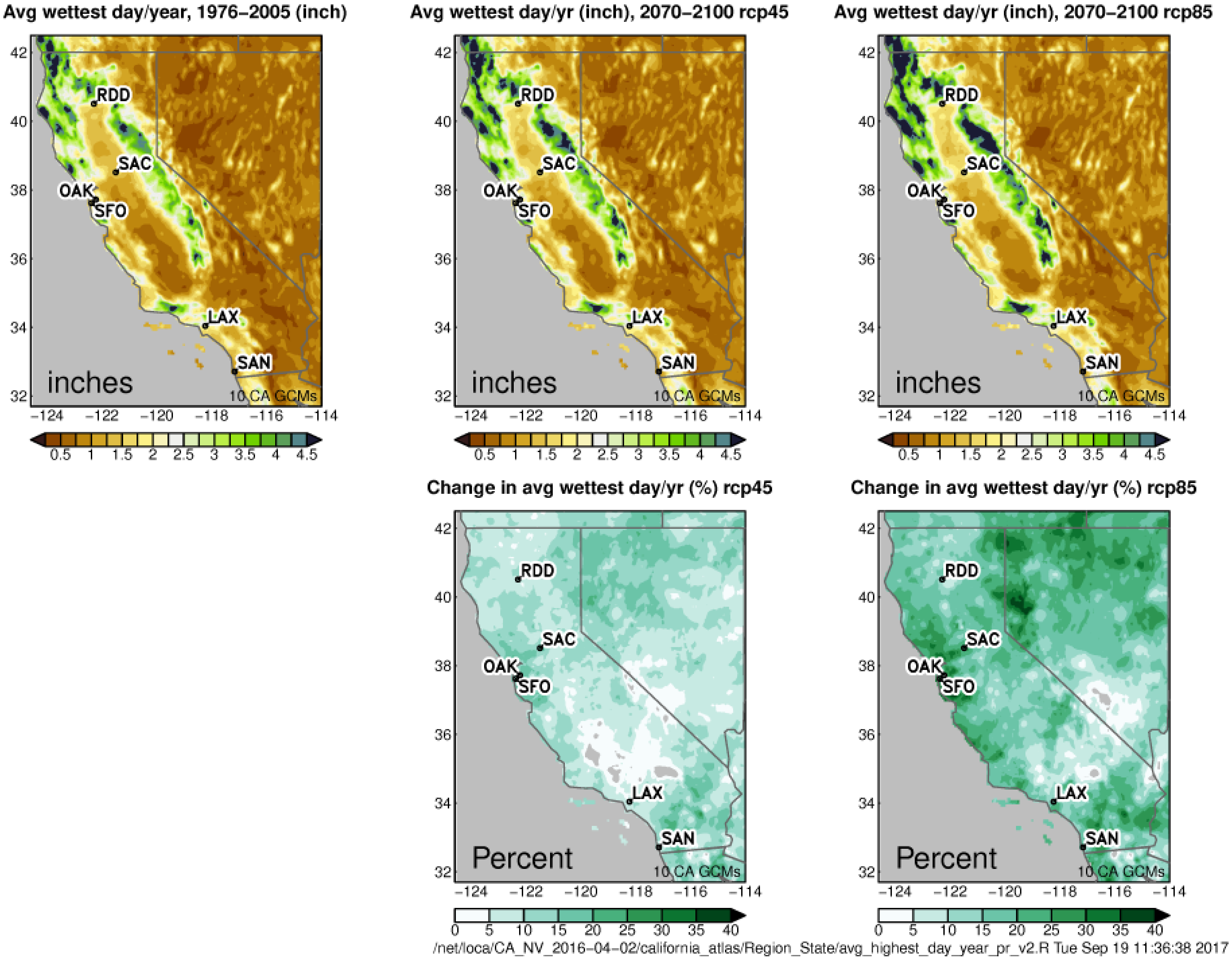

Avg wettest day/year, 1976–2005 (inch)
Avg wettest day/yr (inch), 2070–2100 rcp45
Avg wettest day/yr (inch), 2070–2100 rcp85
Change in avg wettest day/yr (%) rcp45
Change in avg wettest day/yr (%) rcp85
RDD
SAC
OAK
SFO
LAX
SAN
inches
Percent
10 CA GCMs
42
40
38
36
34
32
−124 −122 −120 −118 −116 −114
0.5 1 1.5 2 2.5 3 3.5 4 4.5
0 5 10 15 20 25 30 35 40
/net/loca/CA_NV_2016-04-02/california_atlas/Region_State/avg_highest_day_year_pr_v2.R Tue Sep 19 11:36:38 2017

Figure 11

Relative humidity min (day) change by 2070–2100 w.r.t. 1950–2005, RCP 8.5

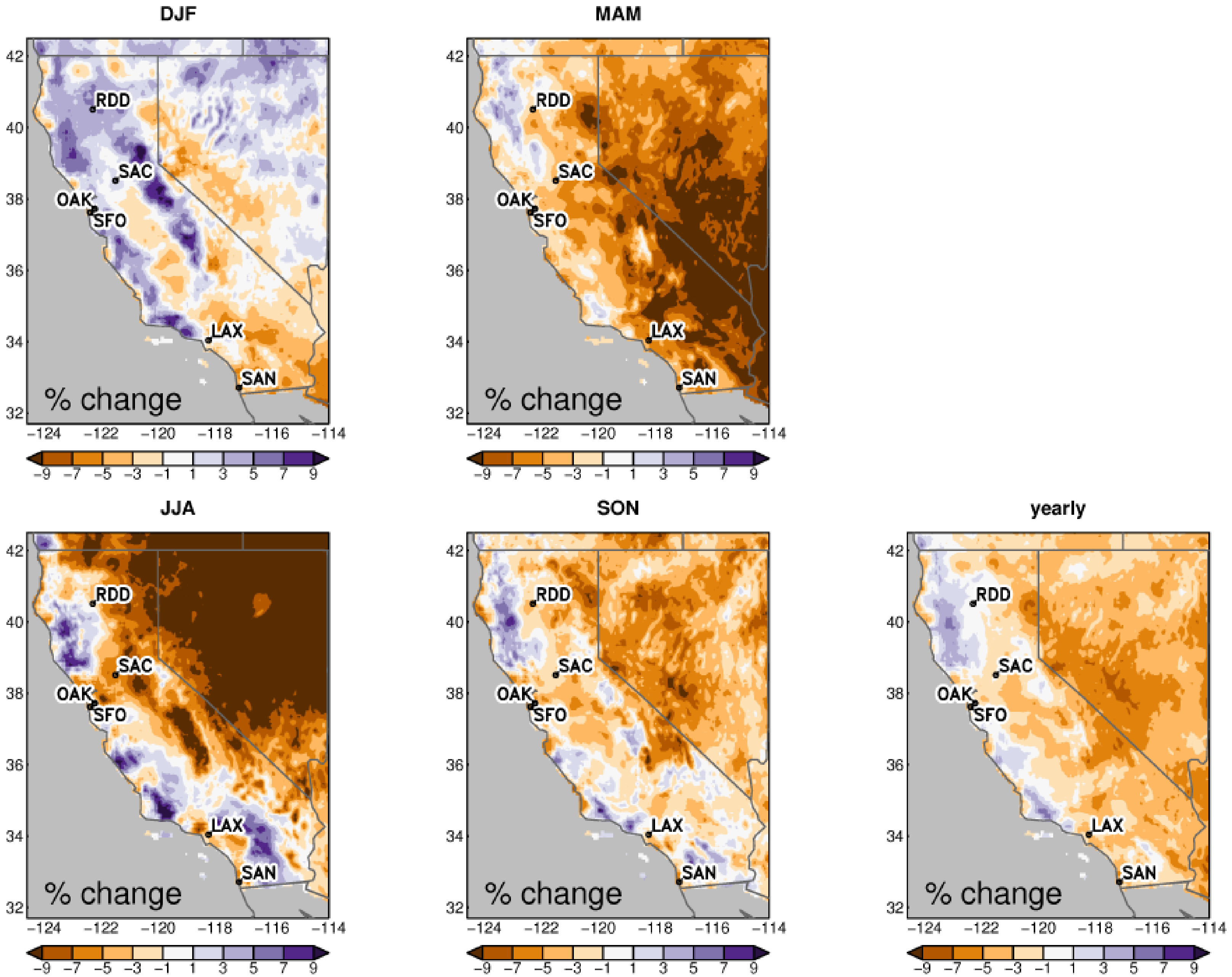
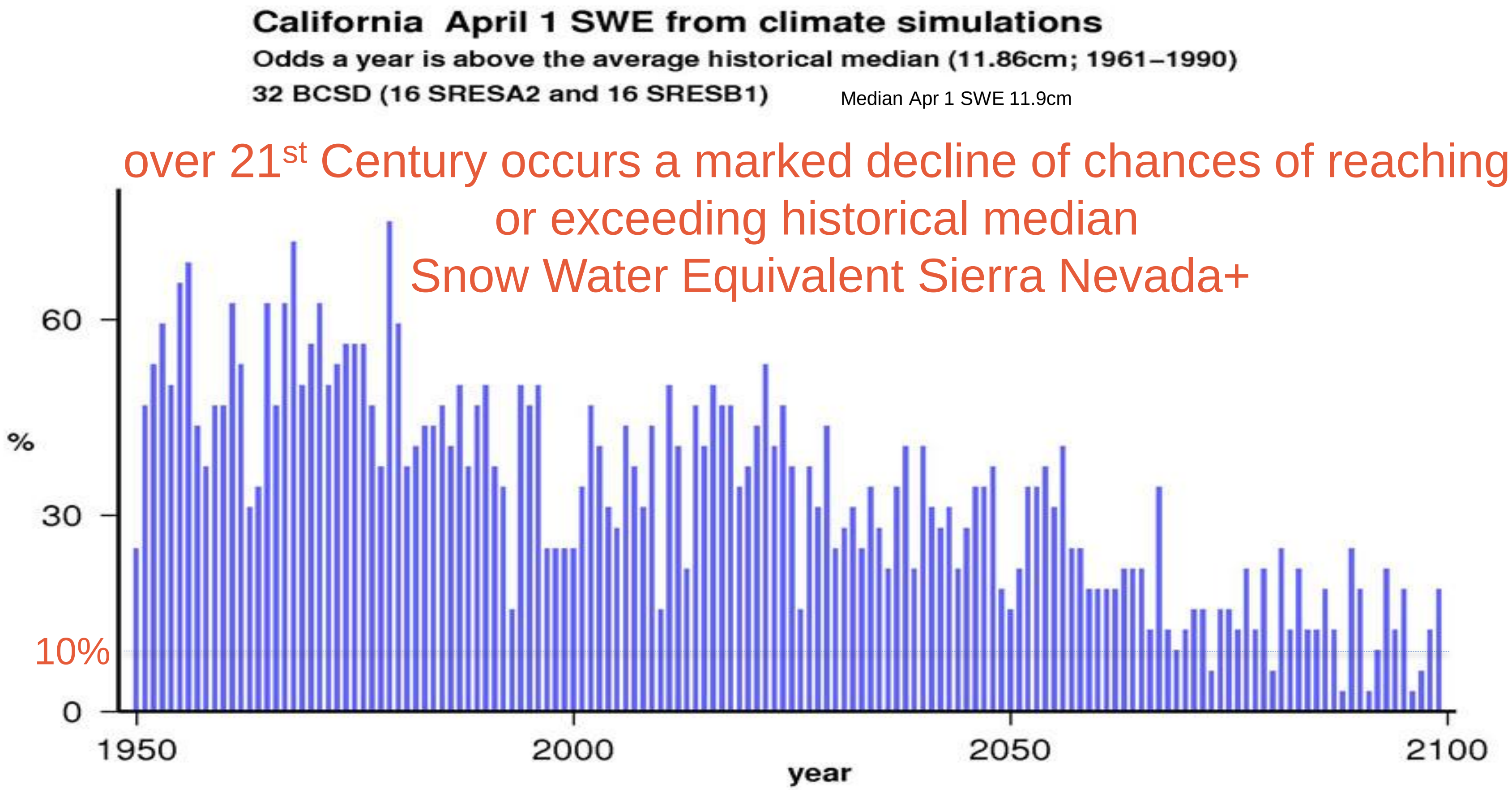
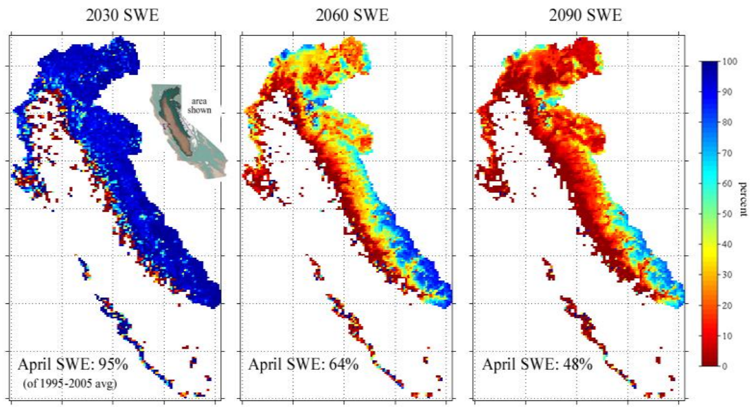


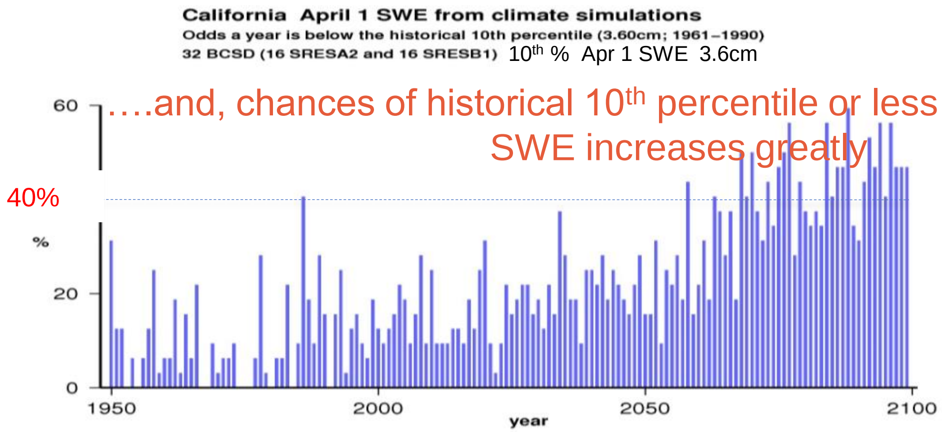
Figure 14



over 21st Century occurs a marked decline of chances of reaching or exceeding historical median Snow Water Equivalent Sierra Nevada+

10%



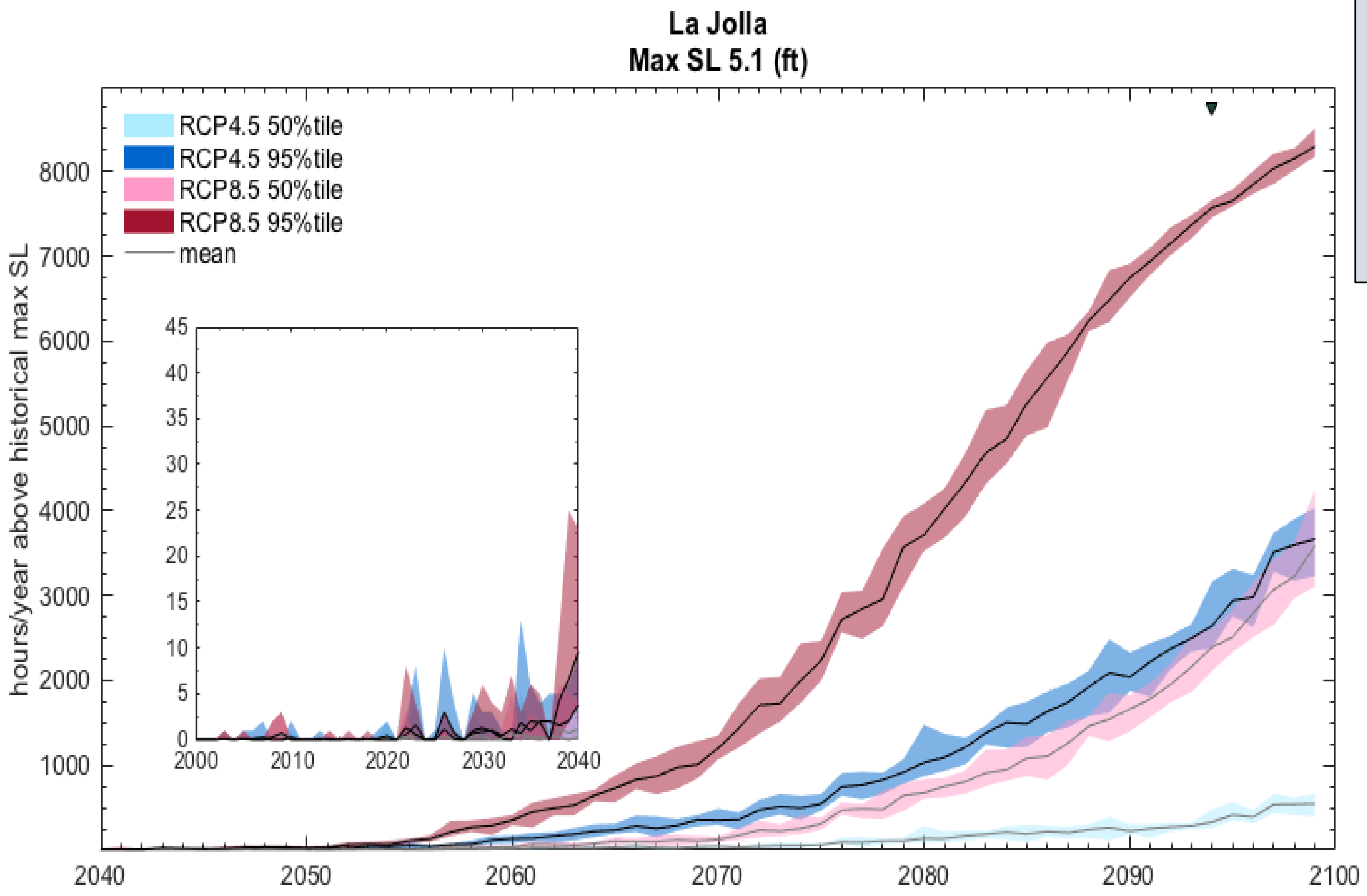


….and, chances of historical 10th percentile or less SWE increases greatly

Sea Level Rise is very likely

projected rate and magnitude have broad range of possible outcomes

greatest impacts when coupled w/ large storms, high tides, El Niño conditions



see *Rising Seas in California* (2017) and new State SLR Guidance

Regional Climate Change is being evaluated in the Fourth National Climate Assessment (NCA4) and the Fourth California Climate Change Assessment

Numerous Other Variable and Measures are being investigated:

Amongst those:

winds
wildfire occurrence
waves
coastal effects
.
.
.

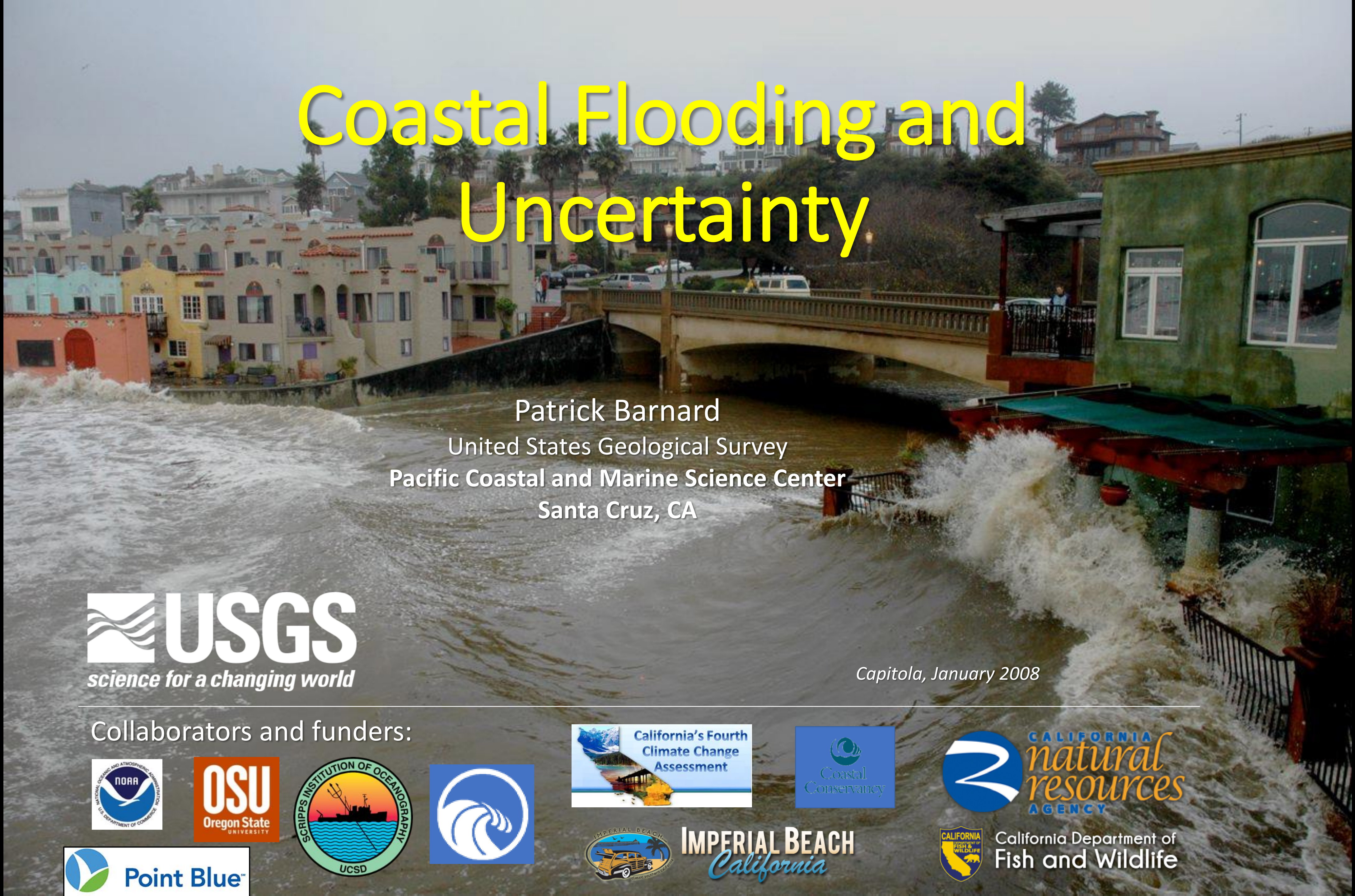
Coastal Flooding and Uncertainty

Patrick Barnard

United States Geological Survey

Pacific Coastal and Marine Science Center

Santa Cruz, CA



Capitola, January 2008

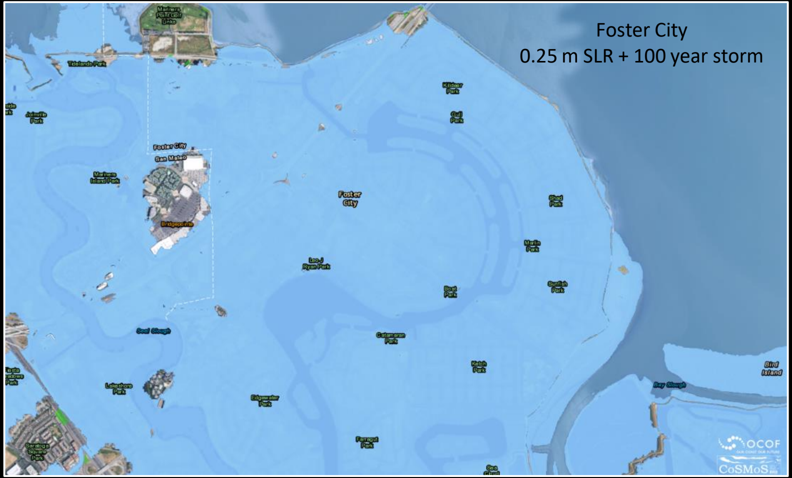
USGS science for a changing world

Collaborators and funders:

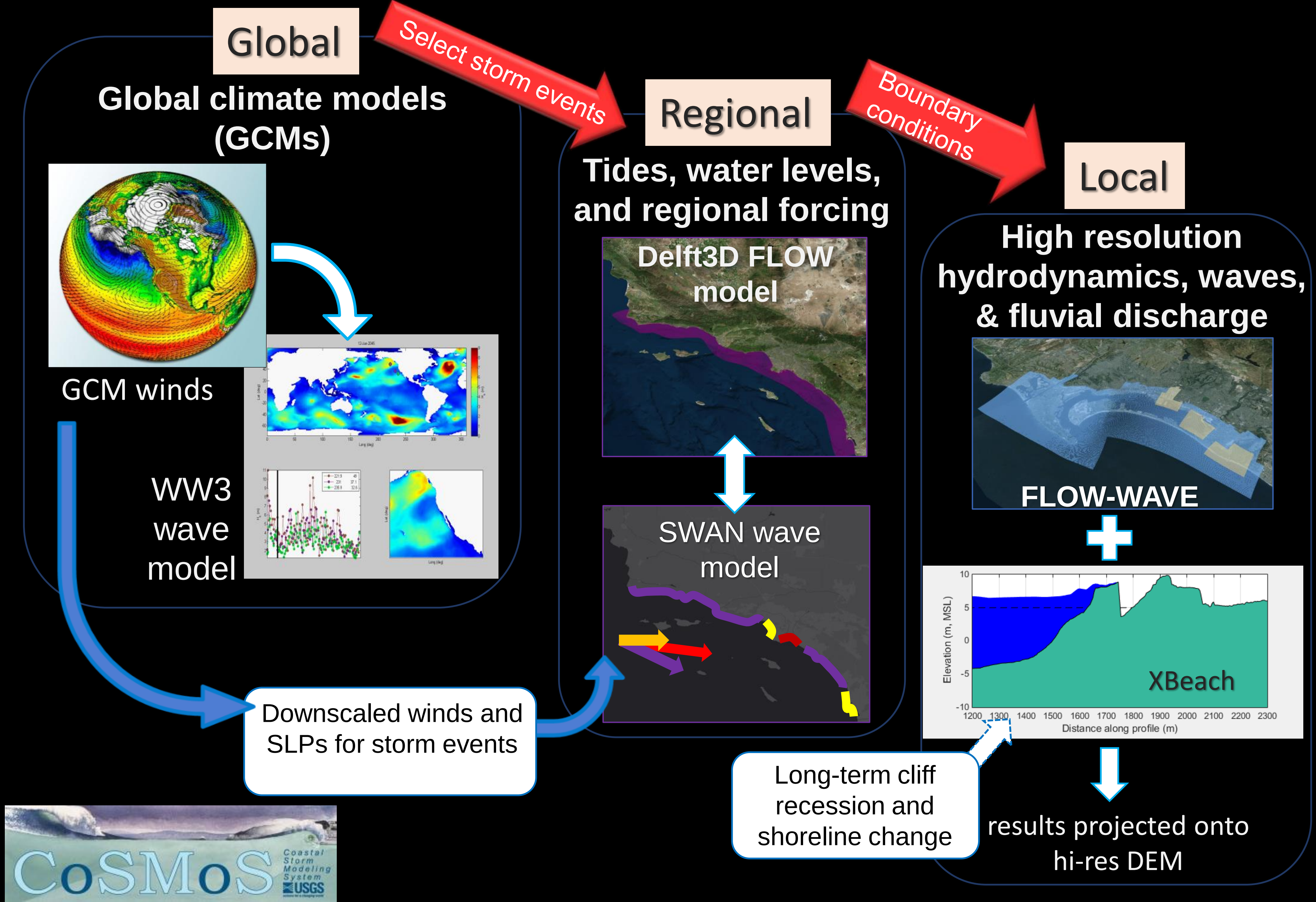
NOAA · OSU Oregon State University · Scripps Institution of Oceanography UCSD · California's Fourth Climate Change Assessment · Coastal Conservancy · California Natural Resources Agency · Point Blue · Imperial Beach California · California Department of Fish and Wildlife

How Big is the Problem?

- Over 1 billion people are expected to live in the coastal zone by 2050
- 27 million people presently live in CA coastal counties
- Over 3 million people in CA at risk of flooding from SLR and storms by the end of the century, in addition to ~$2 trillion in property
- Impact by 2100 could be ~5% of CA GDP
- Bay Area accounts for two-thirds of projected impacts

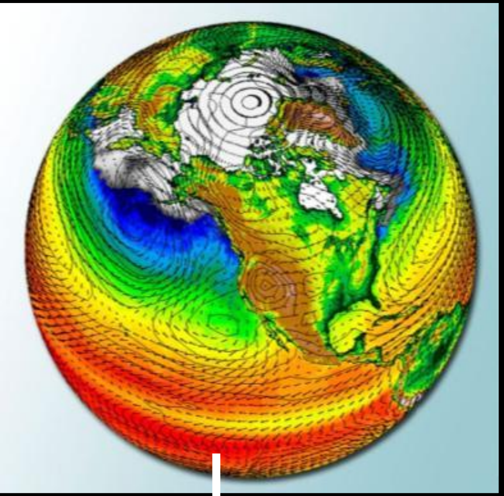


Coastal Storm Modeling System (CoSMoS)



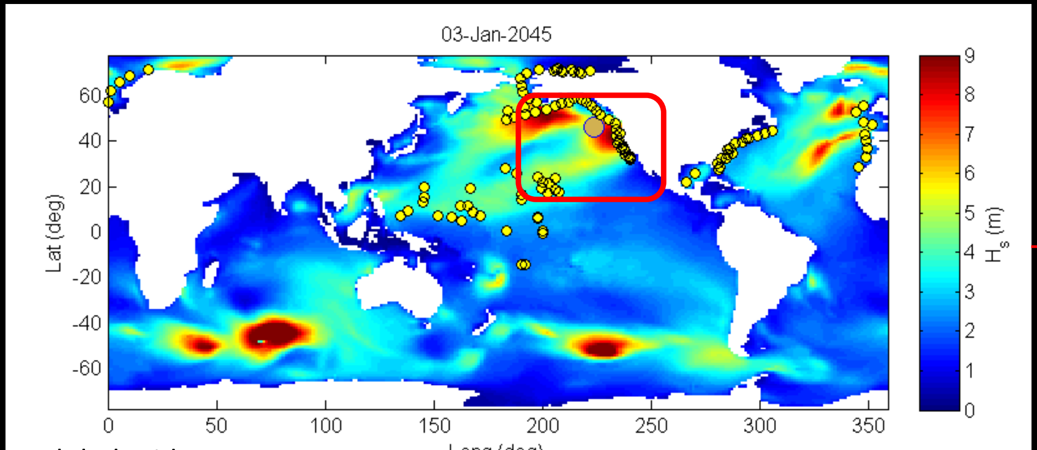
Wave Modeling – Ensemble Approach

1. Global forcing using the latest CMIP5 climate models

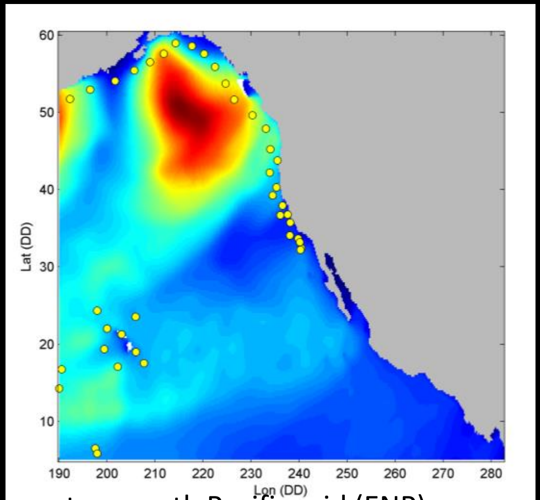


Modeling Center	model	model resolution
Beijing Climate Center, Meteorological Administration, China (BCC)	BCC-CSM1.1	$2.8^o \times 2.8^o$
Institute for Numerical Mathematics, Russia (INM)	INM-CM4	$2^o \times 1.5^o$
Model for Interdisciplinary Research on Climate - AOEI, NIES, JAMSTEC, Japan (MIROC)	MIROC5	$1.4^o \times 1.4^o$
NOAA Geophysical Fluid Dynamics Laboratory	GFDL-CM3	$2.5^o \times 1.5^o$

2. Drives global and the regional ENP wave models (WAVEWATCH3)



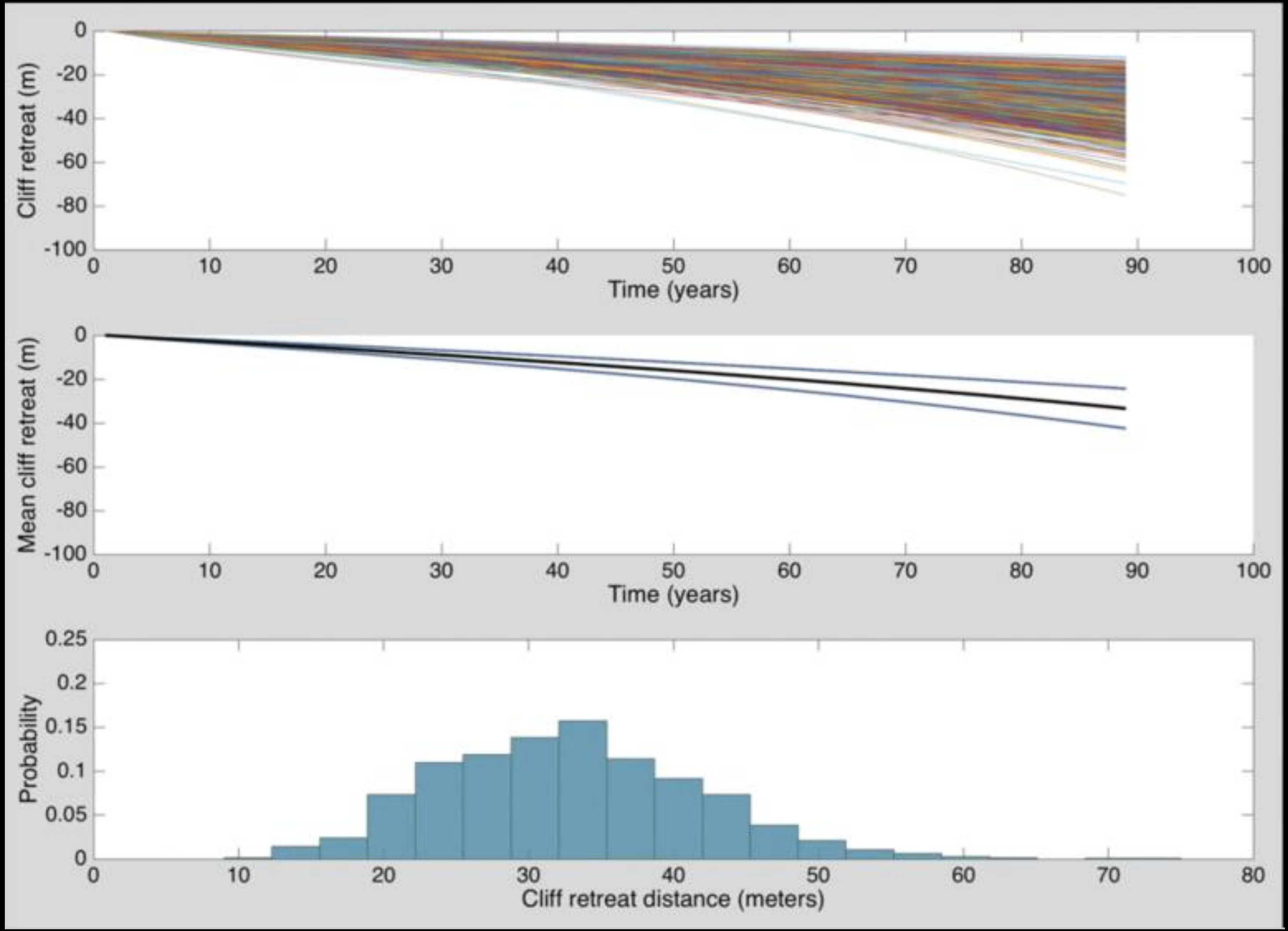
global grid



eastern north Pacific grid (ENP)

Long-term Morphodynamic Change: Sea Cliffs

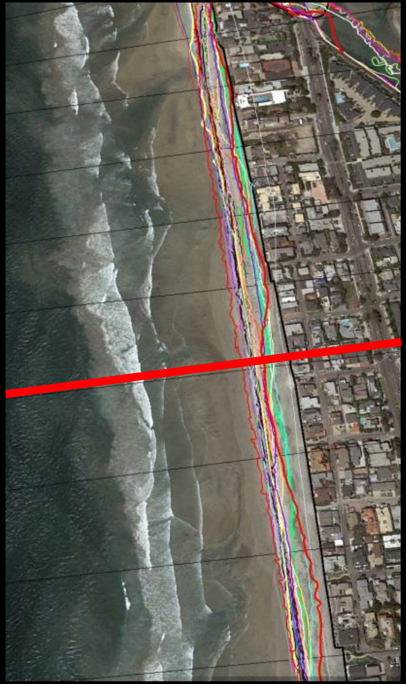
1-D model ensemble (Limber et al., in review)

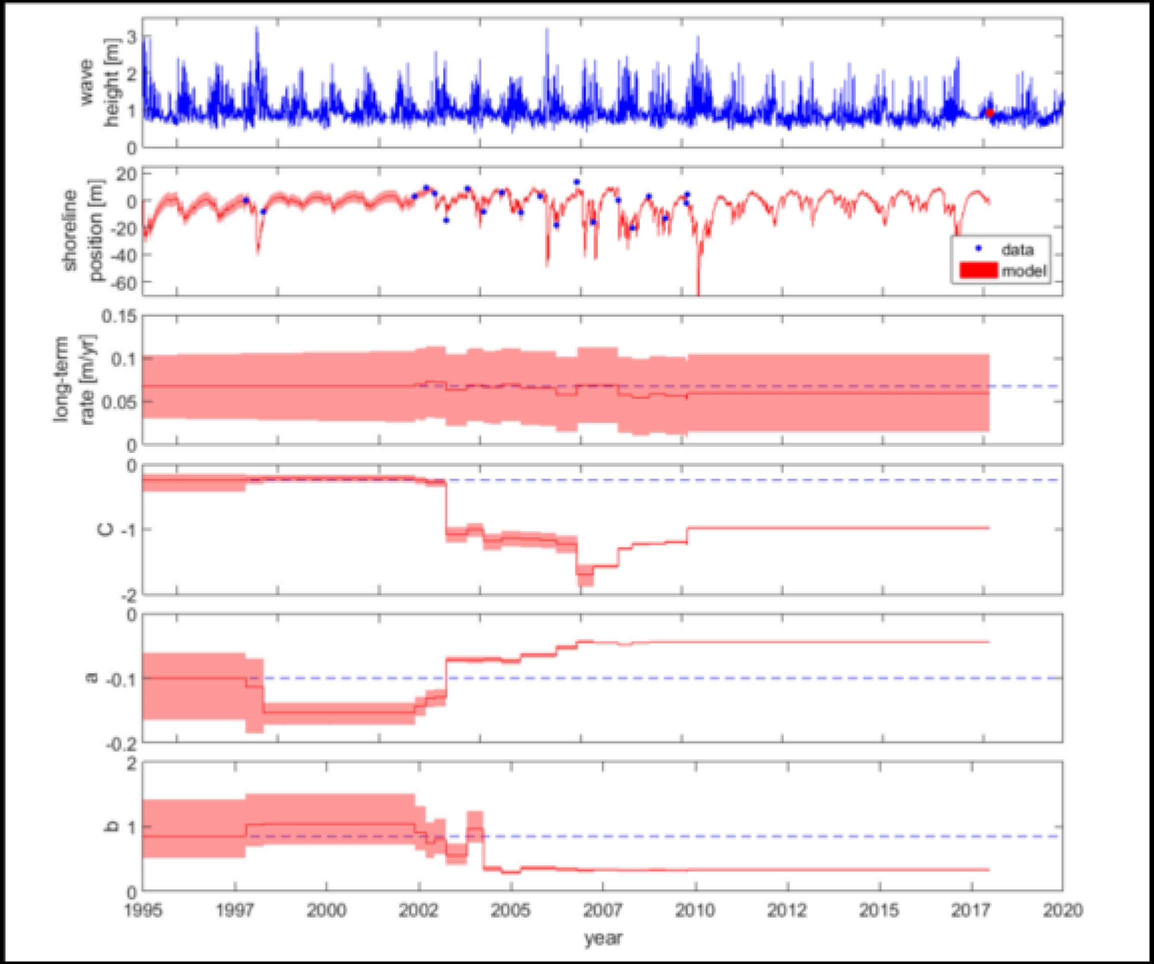


Cliff Retreat

CoSMoS-COAST: Coastal One-line Assimilated Simulation Tool

- A (hybrid) numerical model to simulate long-term shoreline evolution
- Modeled processes include:
  - Longshore transport
  - Cross-shore transport
  - Effects of sea-level rise
  - Sediment supply by natural & anthropogenic sources

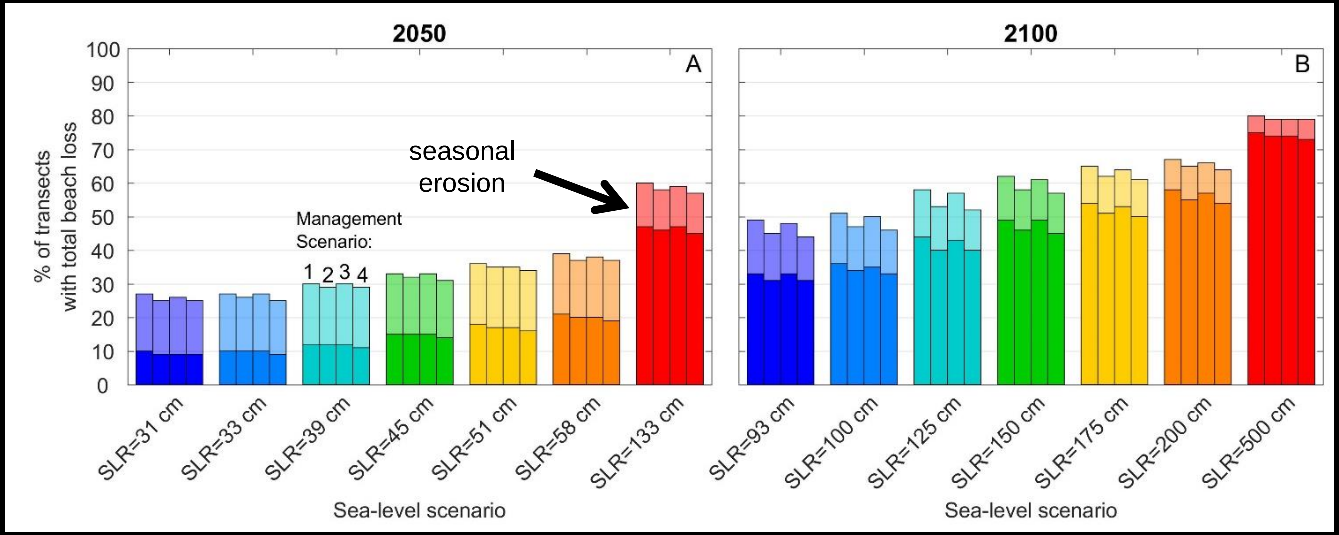




Vitousek, S., Barnard, P.L., Limber, P., Erikson, L.H. and Cole, B., 2017. A model integrating longshore and cross-shore processes for predicting long-term shoreline response to climate change. *Journal of Geophysical Research-Earth Surface*, http://dx.doi.org/10.1002/2016JF004065

Projected Beach Change- SoCal

- Many beaches will erode considerably (avg. = ~50 m)

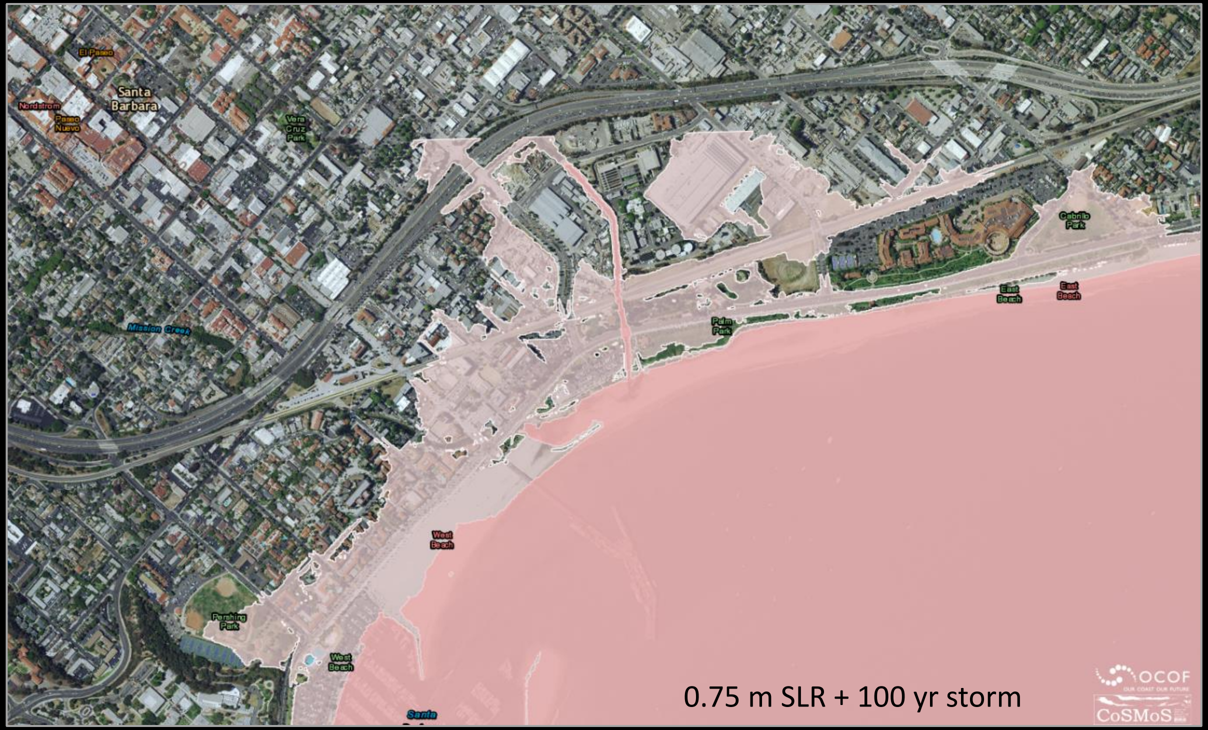


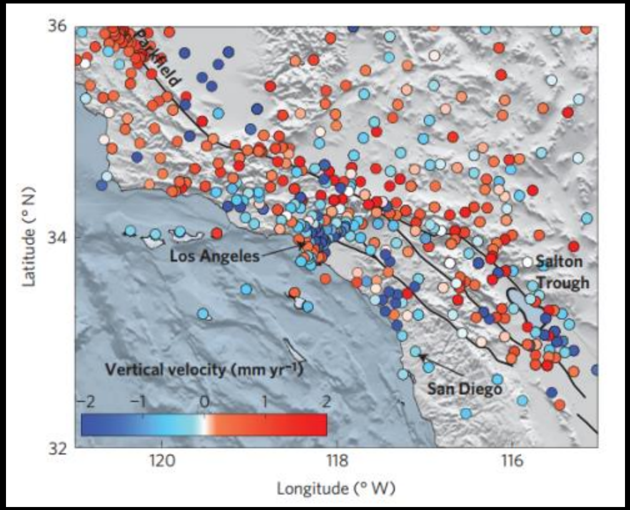
- 31 to 67% of beaches completely eroded*

Vitousek, S., Barnard, P.L., Limber, P., Erikson, L.H. and Cole, B., 2017. A model integrating longshore and cross-shore processes for predicting long-term shoreline response to climate change. *Journal of Geophysical Research-Earth Surface*, Volume 122, 25 pp., http://dx.doi.org/10.1002/2016JF004065

USGS

Flooding Uncertainty





$$\varepsilon = \pm M \pm DEM \pm VLM \pm Marsh$$

Model uncertainty

Vertical accuracy of DEM

(Dewberry 2012)

Vertical land motion

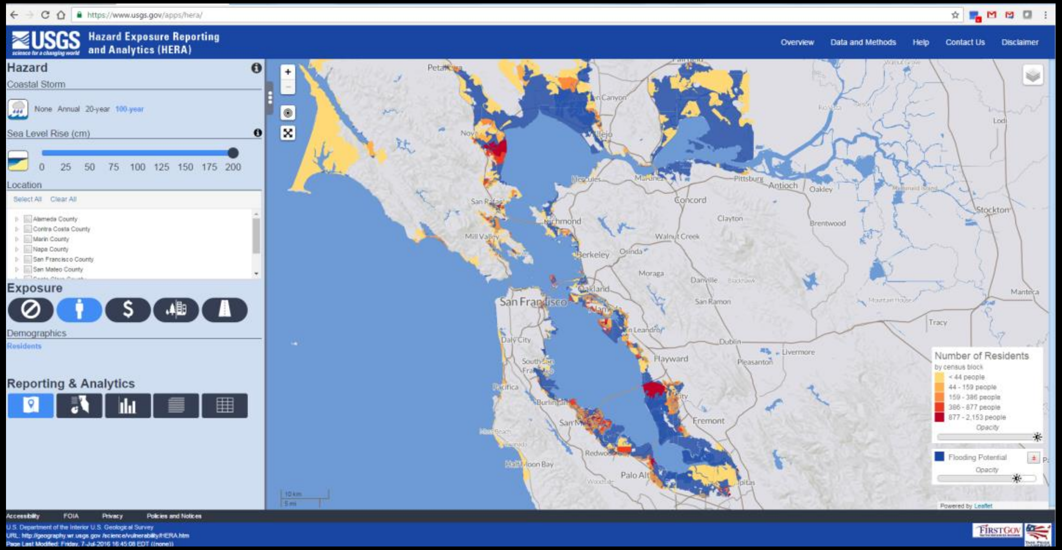
Howell et al., 2016

Marsh accretion/erosion

SF Bay only; PRBO

USGS

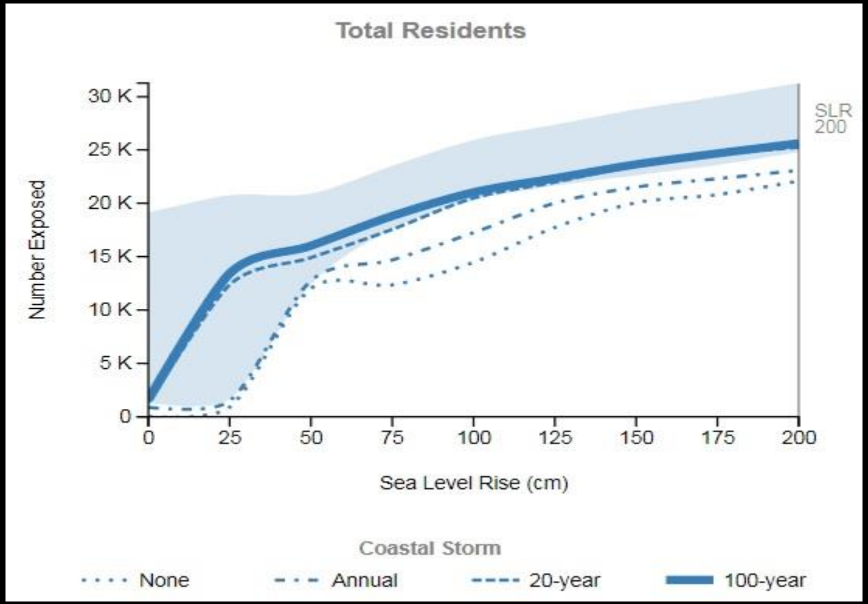
Socioeconomic Impacts



<ins>Hazard Exposure Reporting and Analytics (HERA)</ins>

(2 m SLR + 100 year storm)

- 600,000+ residents
- $150 billion in property
- 4,700 km of roads
- 350 critical facilities



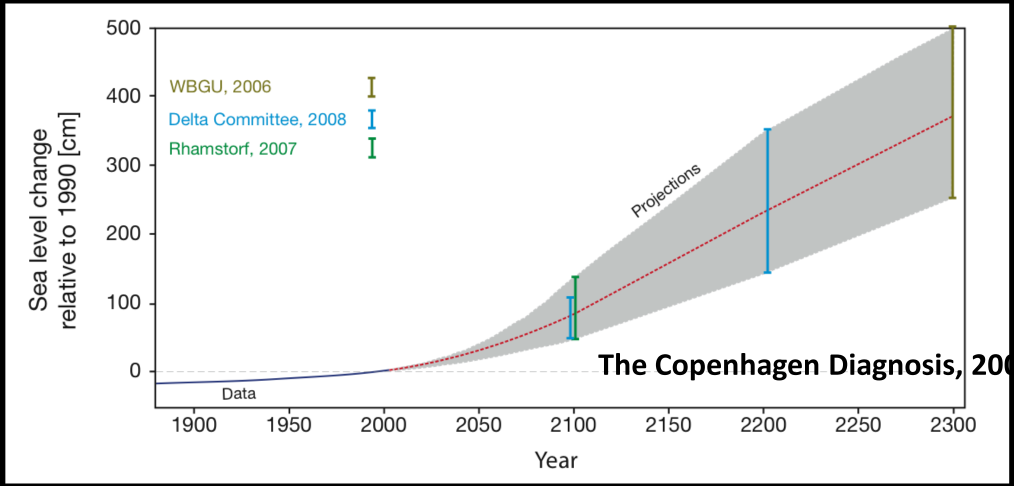
<ins>Redwood City example</ins>

- Clear tipping points
- Uncertainty decreases with time
- Vertical land motion deflects uncertainty band upwards

www.usgs.gov/apps/hera

Other Sources of Uncertainty

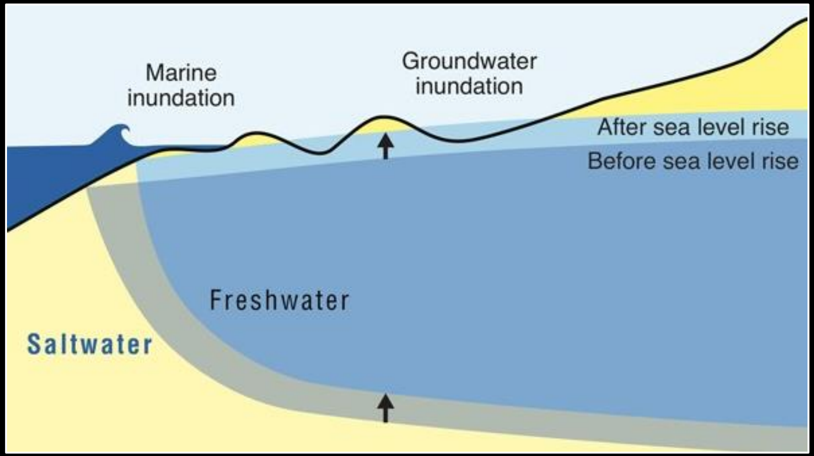
- Sea level rise amount and timing
- El Niño frequency
- Wave climate/ storm patterns
- Beach morphology
- Human intervention

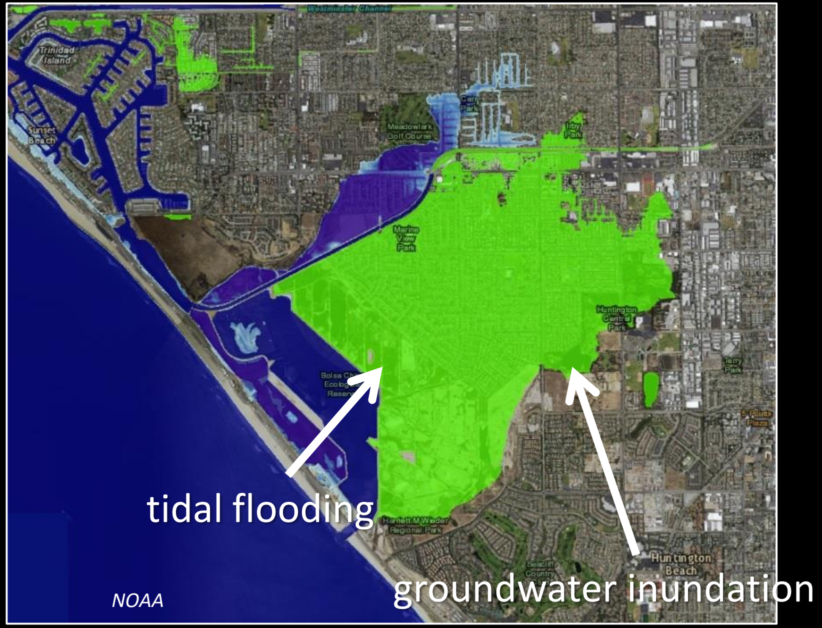


USGS

Groundwater Impacts

- Major issues
  - Inundation
  - Shallower coastal groundwater
  - Saltwater intrusion





- Groundwater inundation
  - May exceed overland flooding and happen much sooner
  - Low-lying areas most vulnerable

Summary

- Critical infrastructure abounds along the coast
- Exposure is significant regardless of uncertainty range
- Data-driven approaches reduce uncertainty
- Cascading effects are poorly understood

*For more information, contact Patrick Barnard: *pbarnard@usgs.gov*

USGS CoSMoS website: *http://walrus.wr.usgs.gov/coastal_processes/cosmos/*

Our Coast - Our Future tool: *www.ourcoastourfuture.org*

HERA Tool: www.usgs.gov/apps/hera

www.californiacoastline.org/

Design of Buildings to Withstand Earthquakes

California Assembly Bill 2800 Webinar

Nicolas Luco, PhD
Research Structural Engineer
U.S. Geological Survey, Golden, CO
National Seismic Hazard Mapping Project

USGS
science for a changing world

International Building Code

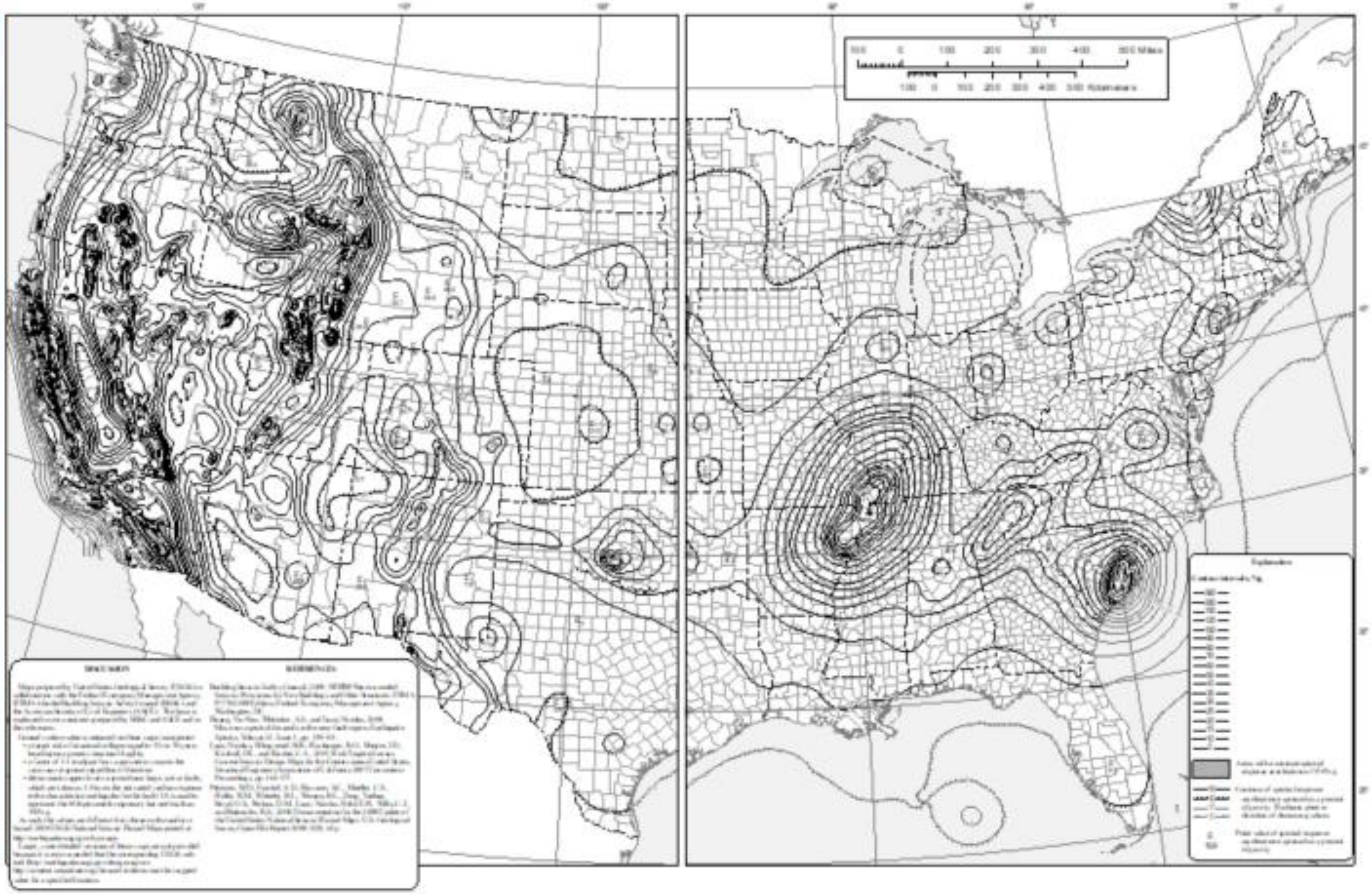


FIGURE 1613.3.1 RISK-TARGETED MAXIMUM CONSIDERED EARTHQUAKE (MCE_R) GROUND MOTION ...

California Assembly Bill 2800 Webinar

"MCE" vs. MCE_R Ground Motion

"Maximum Considered Earthquake"	Risk-Targeted MCE Ground Motion
Uncertain and/or conservative	Includes uncertainty & targets a tolerable level of collapse risk

California Assembly Bill 2800 Webinar

Probabilistic Seismic Hazard Analysis

Bulletin of the Seismological Society of America. Vol. 58, No. 5, pp. 1583–1606. October, 1968

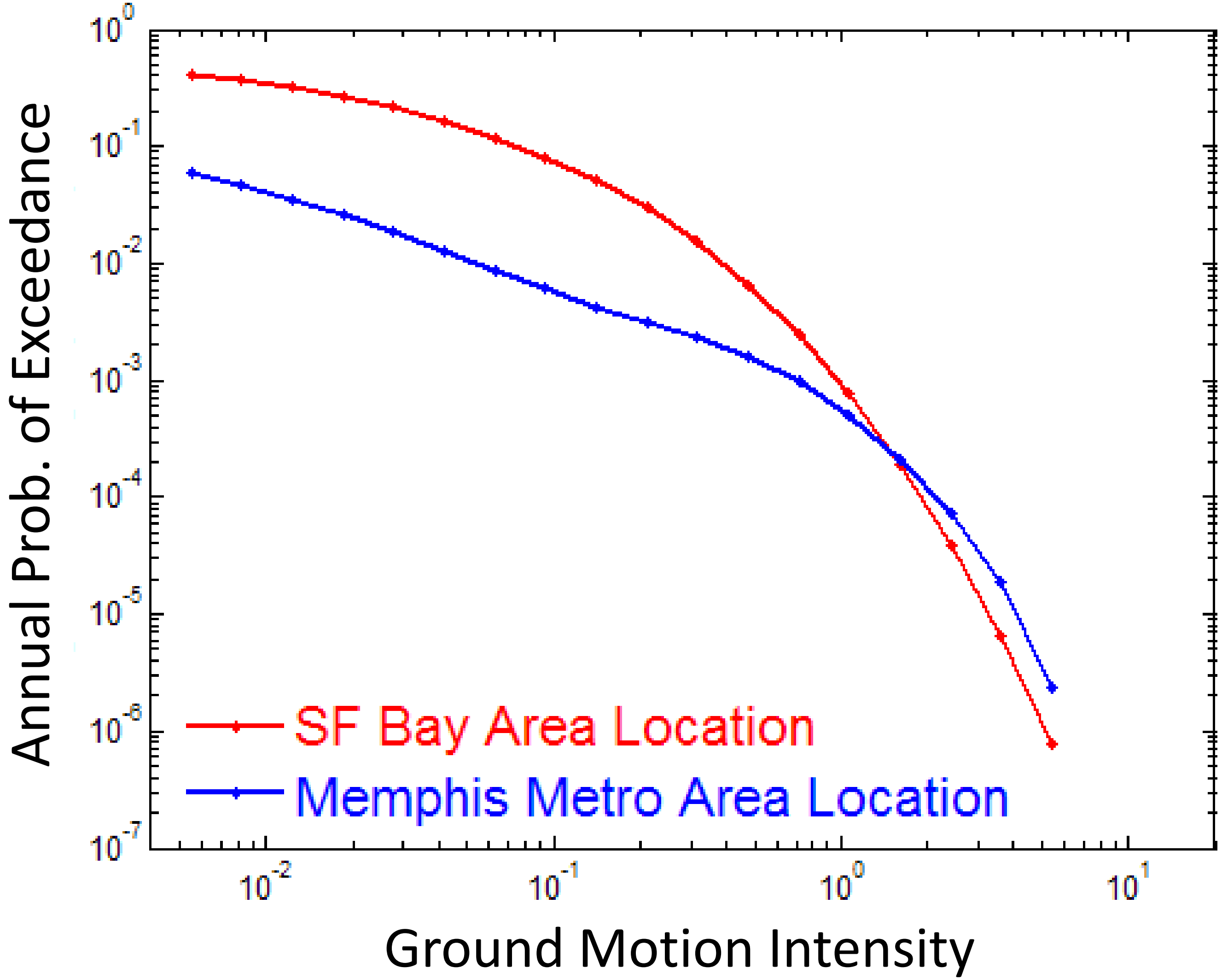
ENGINEERING SEISMIC RISK ANALYSIS

By C. Allin Cornell

ABSTRACT

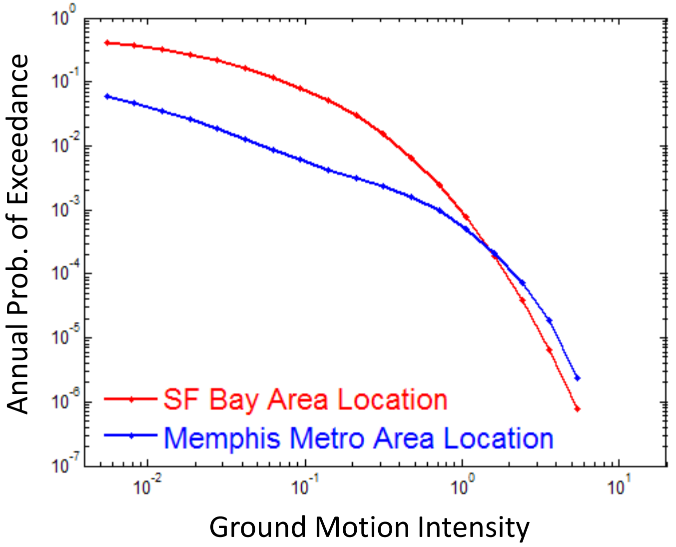
This paper introduces a method for the evaluation of the seismic risk at the site of an engineering project. The results are in terms of a ground motion parameter (such as peak acceleration) versus average return period. The method incorporates the influence of all potential sources of earthquakes and the average activity rates assigned to them. Arbitrary geographical relationships between the site and potential point, line, or areal sources can be modeled with computational ease. In the range of interest, the derived distributions of maximum annual ground motions are in the form of Type I or Type II extreme value distributions, if the more commonly assumed magnitude distribution and attenuation laws are used.

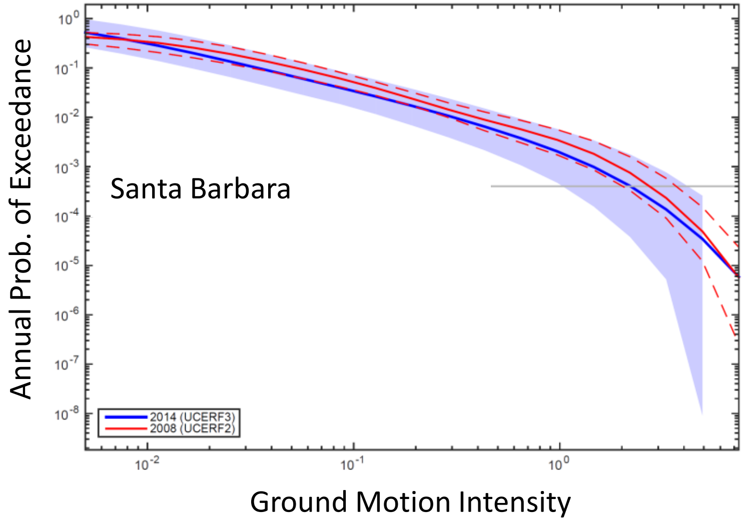
Primary Output from PSHA



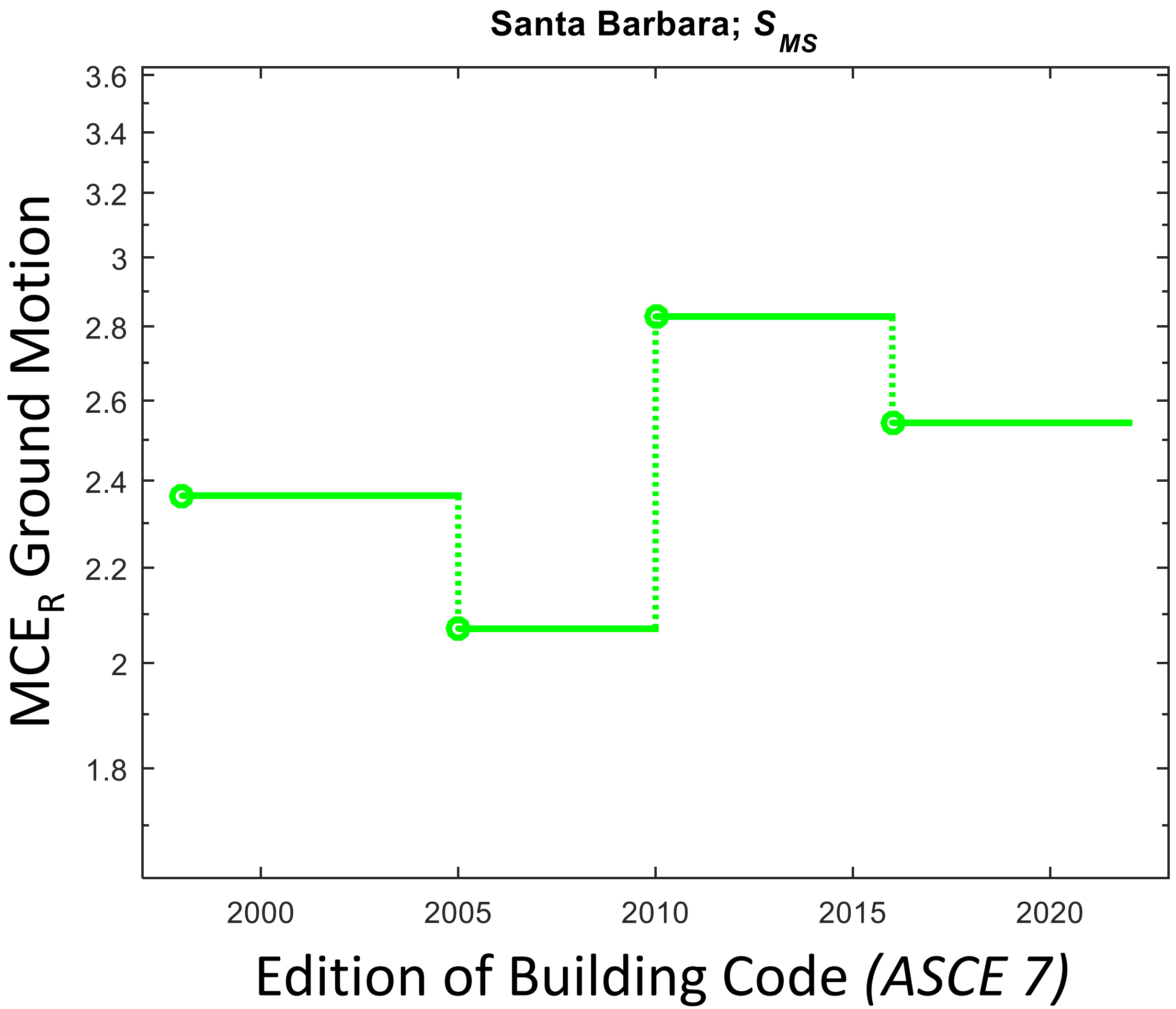
Aleatory & Epistemic Uncertainty

Aleatory Uncertainty, e.g., …	Epistemic Uncertainty, e.g., …
• in whether or not an earthquake occurs • in earthquake magnitude (M) • in ground motion for a given M (and distance, etc.)	• in chance of earthquake based on limited data • in maximum M • in ground motion from different models





Instability over Time



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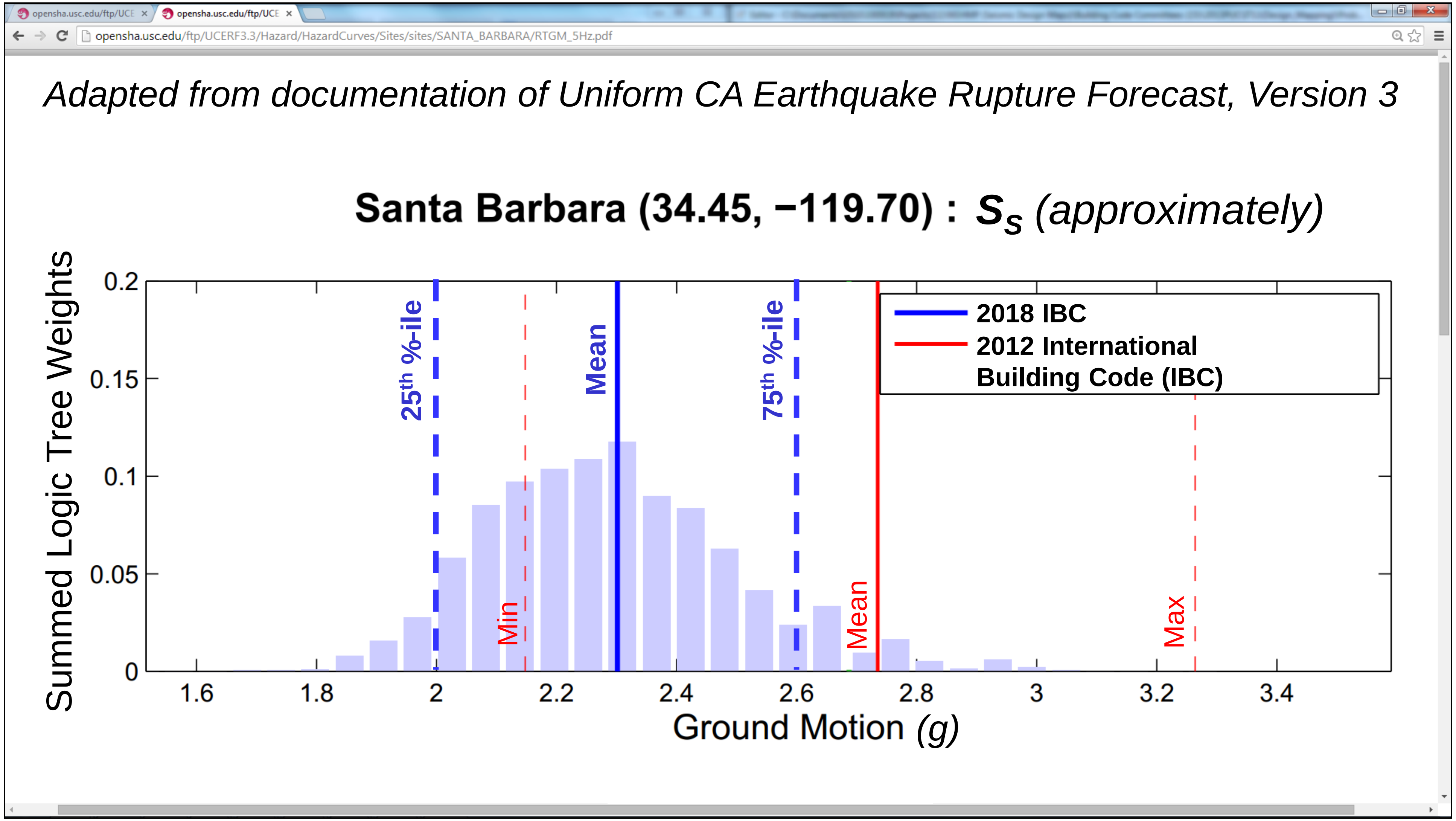
Instability w.r.t. Uncertainty



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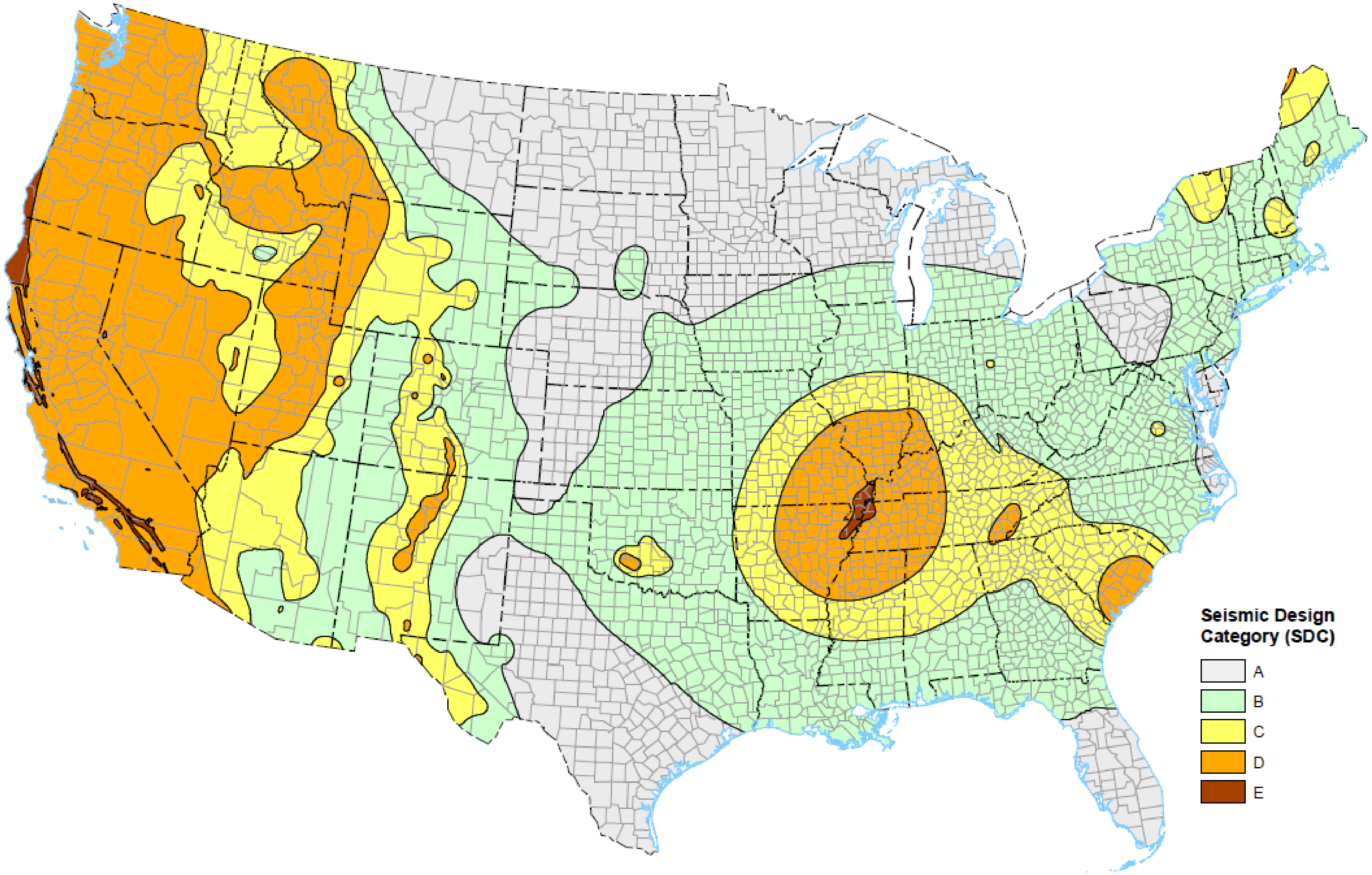
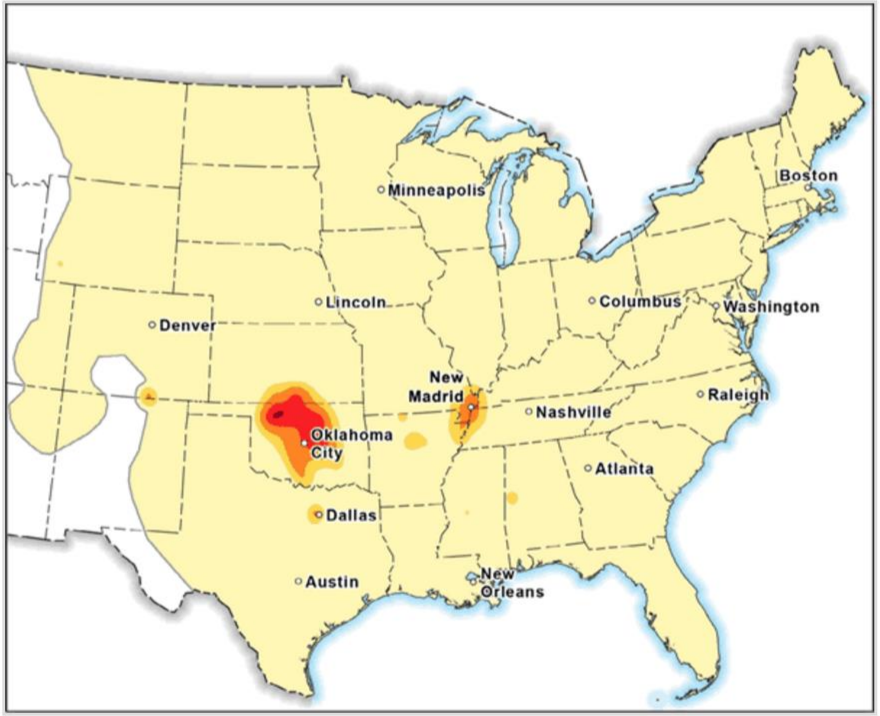
Subjective (but Informed) "Zone Maps"



Induced-Seismicity PSHA

2016 One-Year Model
earthquake.usgs.gov/hazards/induced/

2016 One-Year Model



USGS Open-File Report

2016 One-Year Seismic Hazard Forecast for the Central and Eastern United States from Induced and Natural Earthquakes - OFR-2106-1035

USGS News Release

USGS Science Feature

Induced-Seismicity PSHA

Induced Seismicity in Groningen

Assessment of Hazard,
Building Damage and Risk

November 2017

By Jan van Elk and Dirk Doornhof

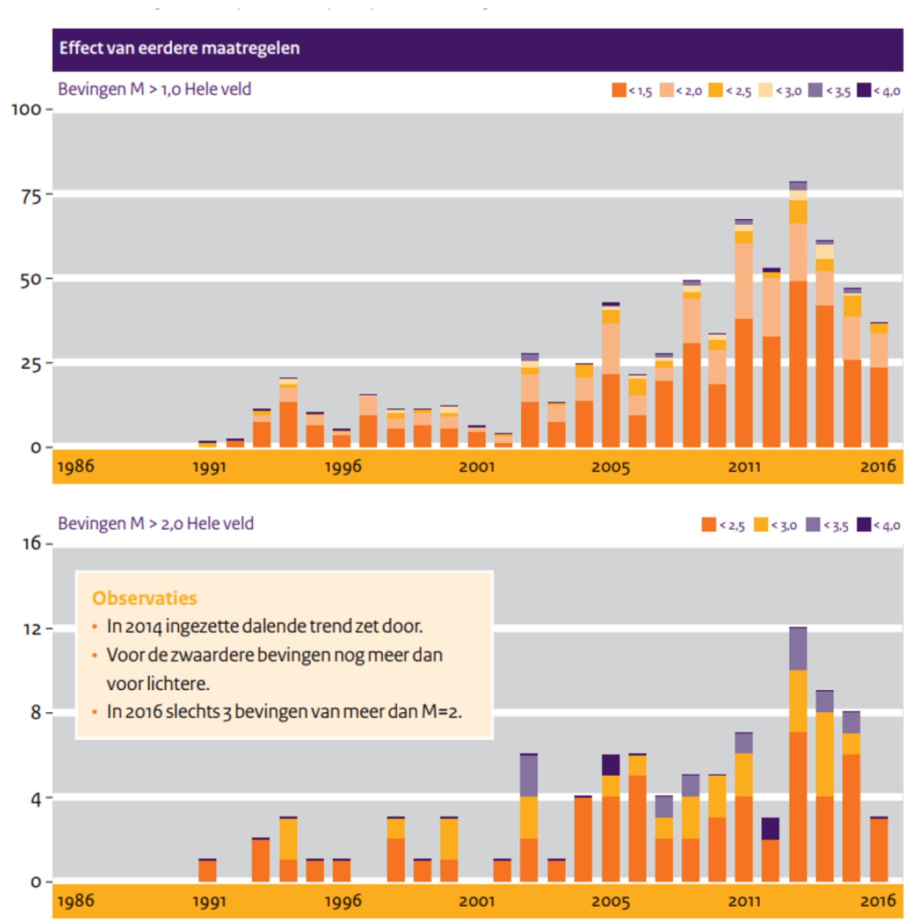


Figure 2.1 The number of earthquakes with magnitude $M_L \geq 1$ (above) and $M_L \geq 2$ (below). The figure was taken from the annual report of SodM (Ref. 47). Observations: The decreasing trend in seismicity from 2014 onwards has persisted in 2016 for both heavier and lighter earthquakes. In 2016 there were only three earthquakes larger than $M_L \geq 2$.

(source: SodM)

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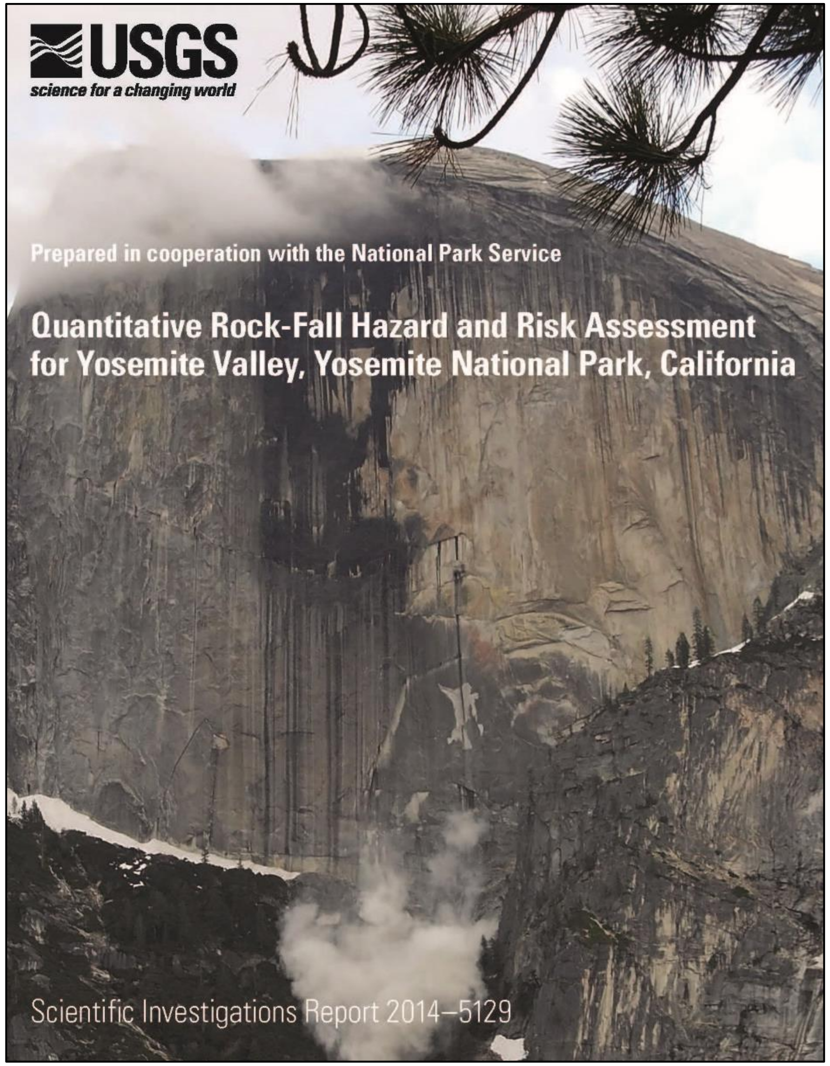
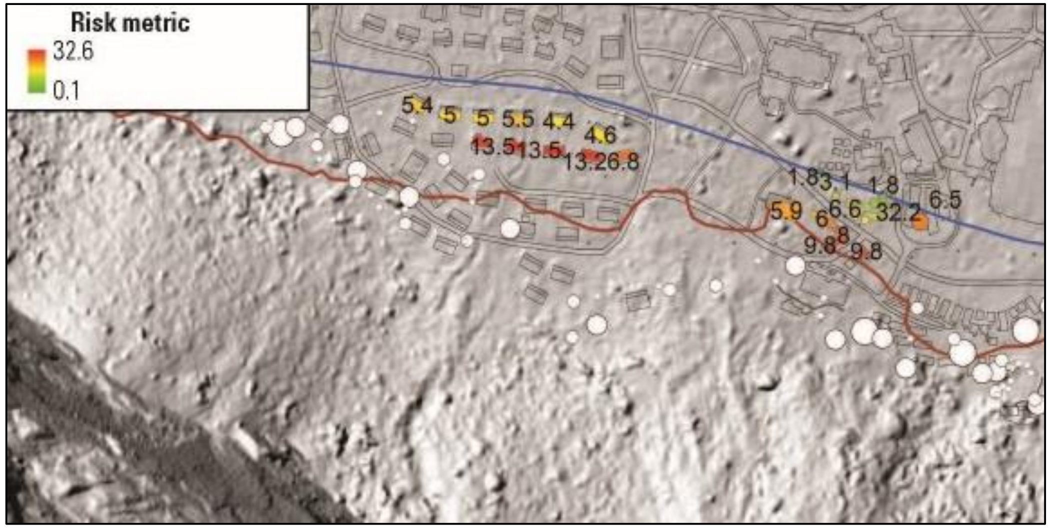
PSHA Analog for Rock Falls





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Summary

- Through collaboration of earthquake scientists and engineers, building codes account for the uncertainties (via PSHA)
- Instability of PSHA outputs over time due to epistemic uncertainties have become an issue, but are being addressed
- One-year induced-seismicity PSHA outputs have not yet been incorporated into building codes, but are being discussed

Discussion and Q&A

Morgan Page

Patrick Barnard

Dan Cayan

Nico Luca

Thank you!

- The ***Climate-Safe Infrastructure*** Webinar Series continues at least through July 2018; ca. 1 webinar every 2-3 weeks

- Next several webinars will focus on sector-specific infrastructure vulnerabilities and solutions (dates TBD)

- Track webinars and progress of CSIWG at: http://resources.ca.gov/climate/climate-safe-infrastructure-working-group/

- Send questions or requests to Elea Becker Lowe at: Elea.Beckerlowe@resources.ca.gov